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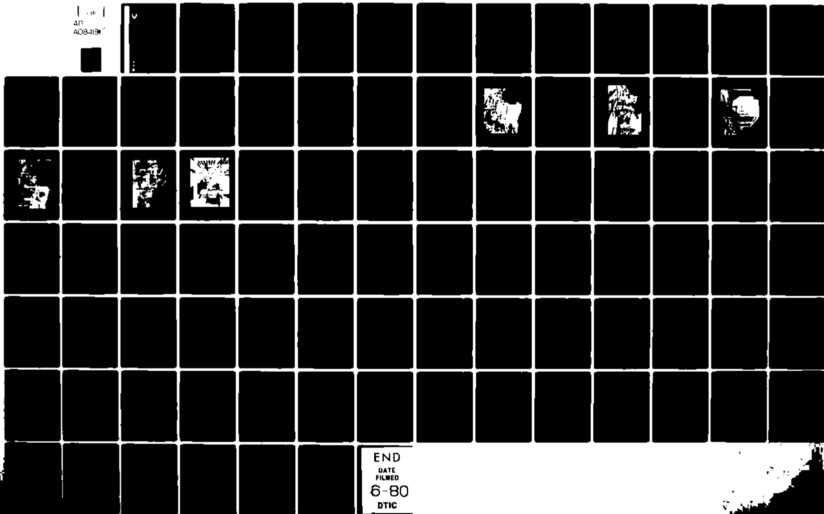

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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
CORADCOM- 79-0789-1

MANUFACTURING METHODS AND TECHNOLOGY PROGRAM FOR RUGGEDIZED TACTICAL FIBER OPTIC CABLE

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FIRST QUARTERLY PROGRESS REPORT
FOR PERIOD
JULY 1, 1979 THRU SEPTEMBER 30, 1979

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This report covers the first quarter~~, July thru September 1979,~~ of the Manufacturing Methods and Technology Program for Ruggedized Tactical Fiber Optic Cable. The scope of this quarter's effort, as reported herein, includes the following tasks and achievements:

(1) Cable Process Optimization;

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~~a.~~ Selection and ordering of polyurethanes for cable jackets, and

~~b.~~ Fabrication and optical testing of the first engineering sample;

(2) Facilitization:

a. High speed strander setup and operation,

b. Extruder setup, and

c. Fiber optic measurement station design; and

(3) Secondary Performance Milestones:

~~a.~~ 1st sample cable induced attenuation measurements.

In addition to reporting progress on these milestones the report covers any revisions or improvements in process, equipment, tooling manufacturing flow and specifications. Key personnel on the program are identified. The program milestones for the next quarter are listed.

ITT Electro-Optical Products Division

MANUFACTURING METHODS AND TECHNOLOGY PROGRAM

FOR RUGGEDIZED TACTICAL FIBER OPTIC CABLE

FIRST QUARTERLY PROGRESS REPORT

FOR THE PERIOD JULY 1, 1979 THRU SEPTEMBER 30, 1979

Object of Program:

To Establish an Automated Production Process for Ruggedized Tactical Fiber Optic Cable

Contract No DAAK80-79-C-0789

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Roanoke, Virginia

ABSTRACT

This report covers the first quarter, July thru September, 1979, of the Manufacturing Methods and Technology Program for Ruggedized Tactical Fiber Optic Cable. The scope of this quarters effort, as reported herein, includes the following tasks and achievements:

1. Cable Process Optimization
   a. Selection and ordering of polyurethanes for cable jackets.
   b. Fabrication and optical testing of the first engineering sample.
2. Facilitization
   a. High speed strander setup and operation.
   b. Extruder setup
   c. Fiber optic measurement station design
3. Secondary Performance Milestones
   a. 1st sample cable induced attenuation measurements.

In addition to reporting progress on these milestones the report covers any revisions or improvements in process, equipment, tooling manufacturing flow and specifications. Key personnel on the program are identified. The program milestones for the next quarter are listed.

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PURPOSE

The purpose of this Manufacturing Methods and Technology (MM&T) Program is to establish automated production processes for Ruggedized Tactical Fiber Optic Cables in accordance with Specification MMT-789898 (Appendix A) dated 2 February 1978, and ECIPPR No. 15.

GLOSSARY

Fused Coupler - Optical coupler for power splitting formed by fusing two or more optical fibers

Injection Fiber - Illuminated fiber used as a measurement light source

ITT EOPD - ITT Electro-Optical Products Division

Lock-In Amplifier - Amplifier used for precise instrumentation measurements in which offset drift is compensated by using a chopped source signal as a reference

NA - Numerical aperture

PCS Fiber - Plastic clad silica fiber

RTV - Silicone buffer coating (room temperature vulcanizing)

1.0 NARRATIVE AND DATA

The following information covers a physical description of the device, performance, effects of processes, and measurement techniques used on this program.

1.1 Device

The following paragraphs define the methods used to optimize the ruggedized tactical fiber optic cable, manufacturing processes, and measurement techniques.

1.1.1 Ruggedized Cable Design

The purpose of this program is to establish an automated production process for a ruggedized tactical fiber optic cable. Figure 1 shows the general cable configuration to be optimized on the program.

The light transmitting elements of the cable are the graded-index optical fibers (Figure 1a) consisting of a glass core (silicon tetra chloride, germanium tetrachloride, phosphorus trichloride, and boron trichloride dopants) and pure silica glass cladding. To preserve the mechanical strength of the glass fibers, they are coated with plastic buffers, the buffer being a solid plastic coating surrounding the optical fiber.

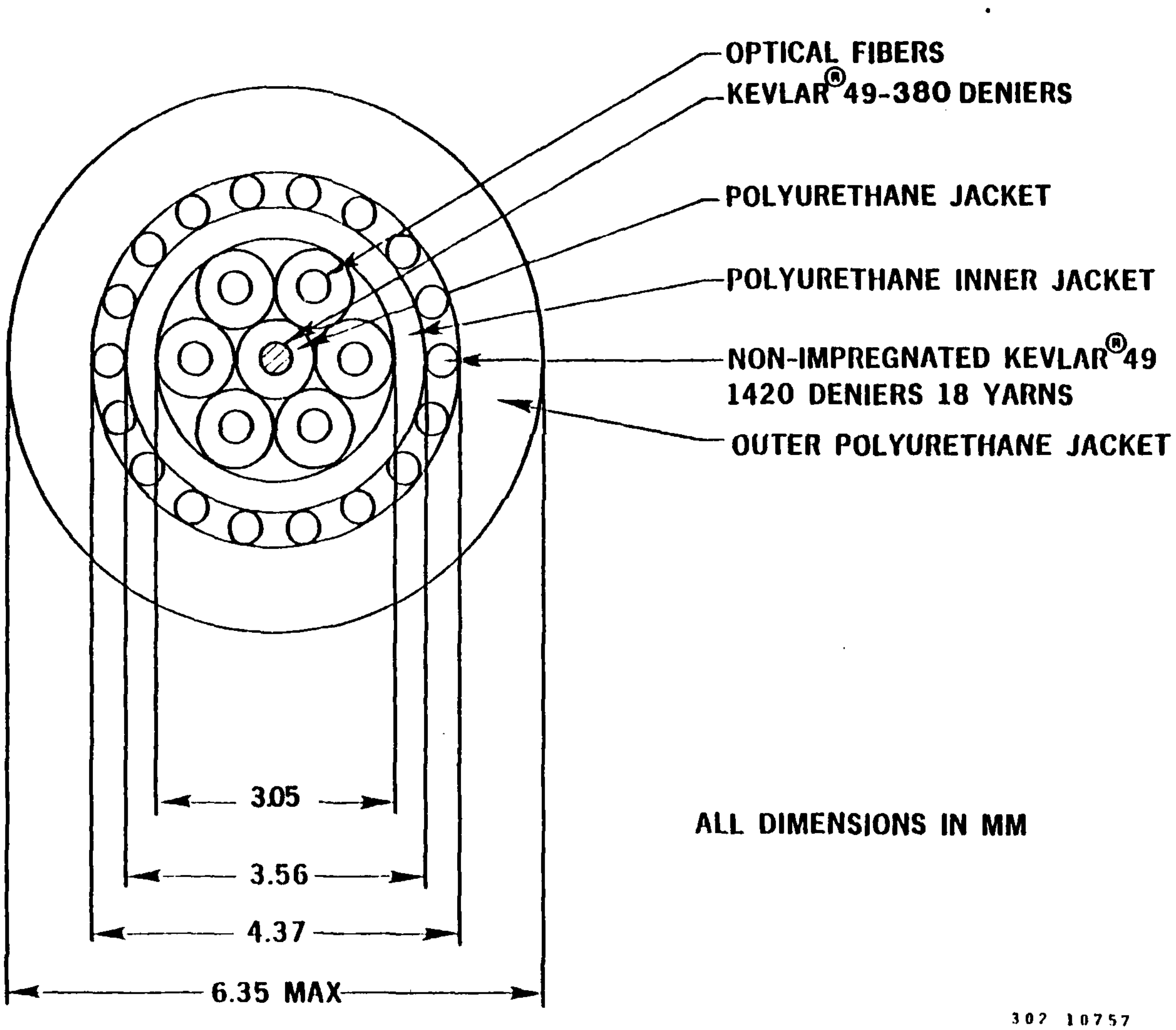


Figure 1. Basic MM&T Cable Design.

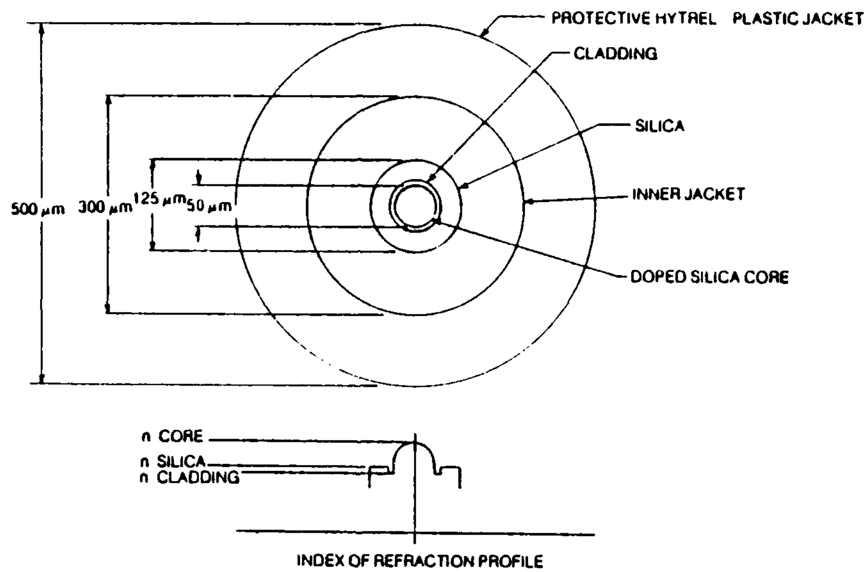


Figure 1a - Wideband Graded Index Multimode Optical Fiber

The graded-index optical fibers are to meet the following specifications at 0.82 μm wavelength after proof loading at 100,000 psi:

a. Fiber core $\geq$50 μm

b. Fiber od 125 μm ±6 μm

c. Attenuation $\leq$5.0 dB/km

d. Dispersion $\leq$2.0 ns/km

e. Numerical aperture (90% power) $\geq$0.20

1.1.1.1 Primary Buffer

A room temperature vulcanizing (RTV) silicone protective coating, Dow Corning Sylguard® 184, is applied by dip coating to a finished diameter of 300 μm immediately after drawing. This protective coating guards the fibers from any initial handling or foreign substances that may damage or reduce the quality of the product and is compatible with the buffering materials. Sylguard is used because of the ease in stripping this material.

1.1.1.2 Secondary Buffer

All fibers have a Hytrel® 7246 buffer layer for additional protection. The layer is tubing extruded to a finished diameter of 0.5 mm. An additional layer is pressure extruded to 1.0 mm to provide the optimum mechanical and environmental performance. The 1-inch extruder line is used for this operation.

Hytrel ® has a very low expansion/contraction coefficient, thereby improving the high/low temperature performance.

1.1.1.3 Center Filler

The center filler shall be a Kevlar ® 49 (380 denier) coated with polyurethane (Roylar ® E-80) to a diameter of 1.0 mm. The center filler provides a cushioning to improve impact resistance.

1.1.1.4 Polyurethane Inner Jacket

The polyurethane inner jacket is extruded after the cabling operation. The polyurethane used is a polyether based compound. It is chosen because of its extreme toughness, abrasion resistance, low temperature flexibility, resistance to hydrolysis, fungus resistance, and excellent stability to atmospheric conditions. This jacket supplies support for the fiber making up the cable core and provides a buffer layer between the fiber and Kevlar ® reducing abrasion.

1.1.1.5 Kevlar ® Strength Member

Kevlar ® 49 has been chosen as the strength member for this application because of its strength versus weight and durability. A total of 18 yarns (1420 denier) is applied helically with a 4.0 inch lay length. The lay length was selected to be greater than that of the fibers to insure that the Kevlar® takes the tensile load. The strength member will provide 400 lb tensile strength at 1% elongation. One percent elongation is the 100 kpsi fiber proof test level.

1.1.1.6 Polyurethane Outer Jacket

The outer jacket material is identical to the inner jacket. Composition will be evaluated on ths program.

1.1.2 Optimization Process

The basic fiber optic cable will be optimized in four phases. The three sets of engineering samples will be selected from this four-phase optimization process. These are described below.

1.1.1.2 Fiber Buffer Optimization (Phase I)

Three buffered fiber diameters of 0.94 mm, 1.02 mm, and 1.14 mm with Hytrel® 7246 shall be evaluated. Also fibers shall be evaluated at 1.0 mm with Hytrel® 4056, Hytrel® 5556, and polyurethane Roylar® E-80. Buffered fiber diameter was varied to reach an optimized value in the cable and fiber performance. Softer Hytrel® grades (4056, 5556) were considered because the materials had a higher resiliency to impact. Polyurethane was also selected for resiliency and to standardize the cable and fiber around a common polyurethane. The physical characteristics of the buffer materials are as follows:

Table 1

Fiber Buffer Materials

Characteristic	Hytrel 7246	Hytrel 5556	Hytrel 4056	Polyurethane Roylar E-80
Hardness, Durometer	72D	55D	40D	80A
Resiliency, Bashore	43	53	62	50
Ultimate Elongation	395	700	800	600
Flex Modulus, psi	75,000	30,000	7,000	3,300
Abrasion Resistance Taber, H-18 Wheel mg/1000 cycles	66	64	100	20
Brittle Point °C	<-70	<-70	<-70	<-62
Compression Set% (70°C) ASTM D-395B	2*	38	36	50

*ASTM D395A Method A

1.1.2.2 Lay Length Evaluation (Phase II)

Cables shall be evaluated with fiber lay lengths of 2.0 in, 2.5 in, and 3.0 in. It is felt that lay lengths shorter than 2.0 inches would cause induced microbending losses and lay lengths greater than 3.0 inches would cause additional tensile load stresses along with high bending stresses.

1.1.2.3 Pressure Versus Tubing Inner Jacket

The inner jacket will be optimized by evaluating pressure versus tubing extrusion process.

1.1.2.4 Outer Jacket

The polyurethane will be optimized by evaluating all four manufacturers of polyether grade urethanes as follows:

Manufacturer	Grade
Uniroyal	Roylar E9-B
B. F. Goodrich	Estane 58300
Upjohn-CPR Div.	2103-80 AWC
Mobay Chemical	Texin 985A

*These represent the softer grade urethanes offered by the four manufacturers applicable for cable extrusion.

1.1.3 Purpose of Phase I Optimization

Phase I of the MM&T program was designed to evaluate the effects of buffered fiber diameter, material type and hardness on the cable performance as follows:

a. Buffered fiber diameter, Hytrel® 7246 (0.94 mm, 1.02 mm, 1.14 mm)

b. Hytrel® hardness effects (4056, 5556, 7246)

c. Material comparison (Hytrel® versus polyurethane)

1.1.3.1 Phase I Optimization

This optimization evaluates the optical fiber buffer material. Six cables have been constructed under this phase using the basic cable design of Figure 1 with the following variations:

a. Design #1 - Hytrel® 7246 fibers, 0.94 mm

b. Design #2 - Hytrel® 7246 fibers, 1.02 mm

c. Design #3 - Hytrel® 7246 fibers, 1.14 mm

d. Design #4 - Hytrel® 4056 fibers, 1.02 mm

e. Design #5 - Hytrel® 5556 fibers, 1.02 mm

f. Design #6 - Polyurethane (Roylar® E-80) fibers, 1.02 mm

1.1.3.2 Manufacturing Problems

All cables were constructed without any problems or difficult areas. Therefore,the various optical fiber bufferings do not affect the manufacturing rate.

1.1.4 Purpose of Phase II Optimization

Phase II of the MM&T program optimizes the fiber lay length (2.0 in, 2.5 in, 3.0 in).

1.1.4.1 Phase II Optimization

This optimization evaluates the cabled fiber lay length and pressure versus tubing extrusion of the inner jacket. Three cables shall be constructed using the high speed strander at 50% of production rate under this Phase II program using the basic cable design of Figure 1 with 1.02 mm Hytrel® 7246 fibers and the following variations:

a. Design No. 1 - 2.0 in lay length

b. Design No. 2 - 2.5 in lay length

c. Design No. 3 - 3.0 in lay length

1.1.4.2 Manufacturing Considerations

Tubing extrusion was selected over pressure extrusion without further engineering samples because the fibers already withstand the impact test. Pressure extrusion would only improve impact performance but would have the following disadvantages:

a. Lower production speed

b. Poor concentricity

c. Lower production yield

d. Equal optical and mechanical performance

e. More material

Construction of engineering samples to evaluate p-essure versus tubing performance was not a requirement in the MM&T program.

1.2 Process, Equipment and Tooling

This section identifies the cable manufacturing process equipment and tooling required to fulfill the program objectives. A description of the main components for each station shall be described after all improvements have been completed.

1.2.1 Cable Manufacturing Process

All manufacturing stations and associated equipment are itemized below.

1.2.1.1 Fiber Rewind Station

This station (Figure 2) will be used to respool, inspect and level wind fibers in preparation for the subsequent stranding operations as indicated on the cable fabrication flow chart (Figure 8, E1). The fiber rewind station shall be equipped with an optical lump/neck down detector (Figure 2, item 2) and a constant-tension compensating payoff (Figure 2, item 1). The lump/neck down detector and constant-tension compensating payoff will allow fibers to be optically inspected for buffer jacket flaws at controlled tensions. The rewinding speed of this unit is 8400 meters/hour. This is ample capacity to respool the 6 fibers required in the cable.

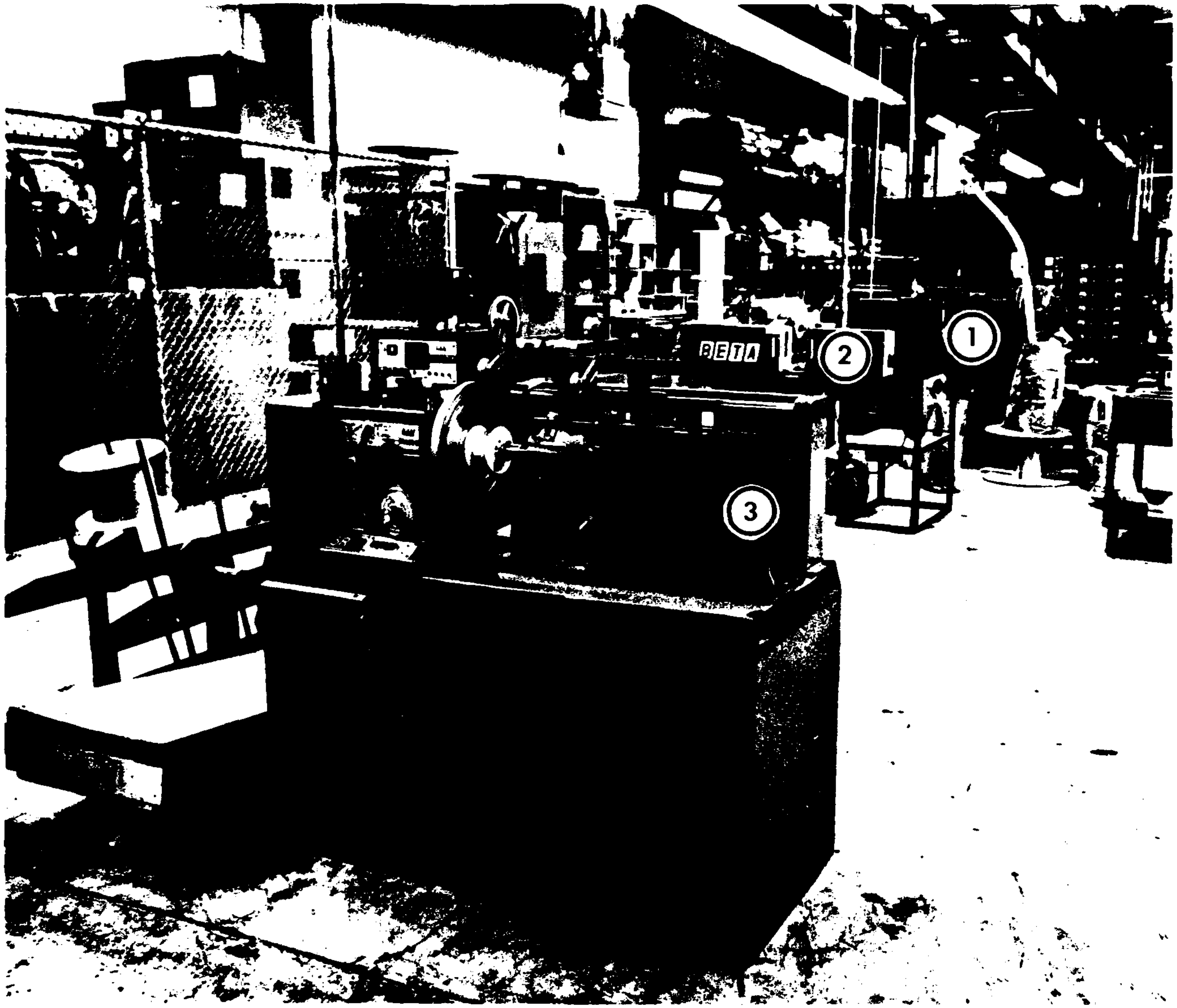


Figure 2. Fiber Rewind Station

To date no problems have surfaced on this new approach to fiber rewinding. The rewinder and lump/neck down units are in-house at EOPD with the payoff unit scheduled to be received in November 1979.

1.2.1.2 Fiber Continuity Check Station

Before the fibers are stranded into a cable bundle it is essential that each fiber's continuity be tested. The unit used at this station (Figure 8, E2) will include a large area light emitting diode and a large silicon detector. The LED and detector will be properly mounted for automatic axial alignment and quick operation.

To complete this unit, minor modifications to existing equipment is all that is required.

1.2.1.3 Kevlar Jacketing Station

This station (Figure 3) is to overcoat an impregnated Kevlar 49-380 denier yarn with a polyurethane jacket which will be used for the central core of the optical bundle as indicated on the cable fabrication flow chart (Figure 8, E3). The exturder to be used is a one inch unit (Figure 3, item 1) with the capacity of pressure extruding the polyurethane jacket at a rate of 45 meters/minute.

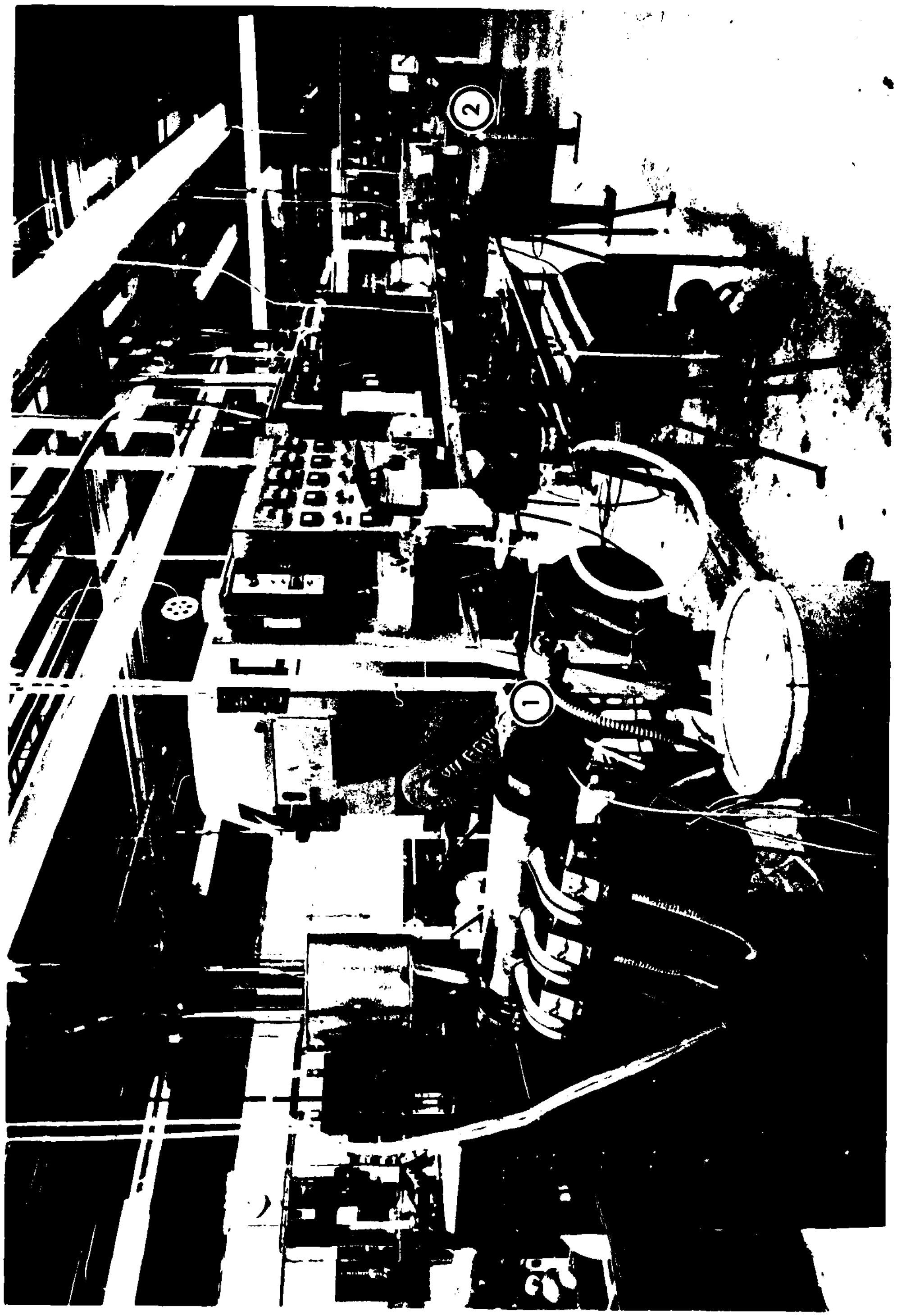


Figure 3. Kevlar Jacketing Station 1" Extruder

This unit is an existing production station. By year end of 1979, the line will be equipped with an automatic diameter controlling process unit equipped with a laser micrometer sensing unit. The components necessary to incorporate this unit into the extrusion line are presently in-house at EOPD. This system provides a feedback signal related to jacket diameter to the line speed control to achieve uniform jacket diameter.

1.2.1.4 Respooling Station for Polyurethane Jacket Kevlar®
This operation (Figure 8, E4) will be completed using the equipment outlined in Paragraph 1.2.1.1. Capacity of this unit is ample to complete both respooling operations.

1.2.1.5 Optical Core Stranding Station
The purpose of this station (Figure 4) is to strand the six optical fibers helically around the Kevlar® central core element as indicated on the cable fabrication flow chart (Figure 8, E5). To do this operation a special high speed stranding unit (Figure 4, item 2) will be used. The unit is presently in the process of checkout at EOPD. The unit is capable of holding four kilometer continuous lengths on the take-up assembly (Figure 4, item 3).

Figure 4. Fiber Stranding Station

This strander was designed for left or right hand lay; however, after changing the lay direction from left to right, the stranding rate was reduced to half. This and another intermittent tension control problem is two payoff bays (Figure 4, item 1) were corrected by the equipment manufacturer.

Efforts now will be concentrated on increasing the stranding speed to meet the MM&T rate.

1.2.1.6 Optical Core Jacketing Station

This station (Figure 5) is to be used to extrude the polyurethane jacket over the optical bundle as indicated on the cable fabrication flow chart (Figure 8, E6). The extruder is a 1 1/2 inch unit (Figure 5, item 2) capable of extruding the above jacket at 30 meters/minute, well over the required MM&T rate.

Experiments have shown that the proposed change of take-ups (Figure 5, item 3) will not be necessary due to improvements made in the sensitivity of the present take-up dancer. No loss increase has been experienced in several cable cores manufactured on this unit since the improvements were incorporated. An automatic diameter control unit with a laser micrometer sensor has been installed on this unit which is similar to the one outlined in 1.2.1.5.

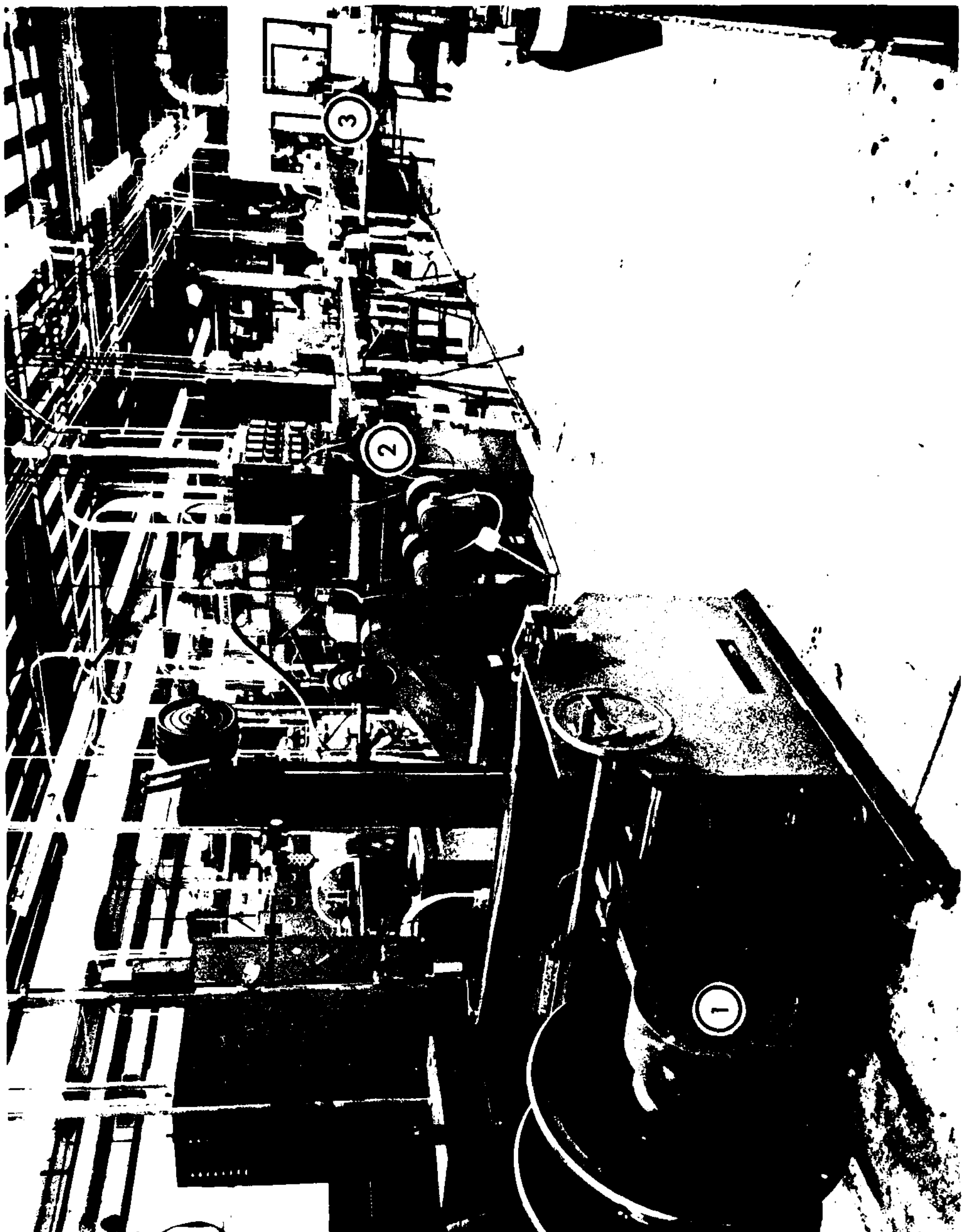


Figure 5. 1 1/2" Extruder Station

1.2.1.7 Kevlar Stranding of Core Station

The purpose of this station (Figure 6) is to strand 18 Kevlar strength members around the jacketed optical core as indicated on the cable fabrication flow chart (Figure 8, E7).

Stranding of the strenth members will be completed using a special serving machine. The unit is currently being fabricated and will be installed at EOPD in early 1980. This unit has the capability of paying off 36 strands at a variety of tensions and lay lengths (Figure 6, items 1,2). The take-up unit (Figure 5, item 3) is capable of handling the 4 km continuous lengths of cable.

The serving line accommodates a full bobbin of Kelvar operating at high speeds and controlled tensions, thus providing a capacity well above the required MM&T rate.

1.2.1.8 Final Jacketing Station

The two-inch extrusion line (Figure 7) will be used to extrude the final outer polyurethane jacket on the ruggedized cable as indicated on the cable fabrication flow chart (Figure 8, E8). The extrusion line (Figure 7, item 2) is capable of extruding the final jacket at a rate of 25 meters/minute.

Installation of this unit is complete with operation being temporarily delayed while desired changes in its original mode of operation are completed. The changes are complete except for the installation of a tach-generator

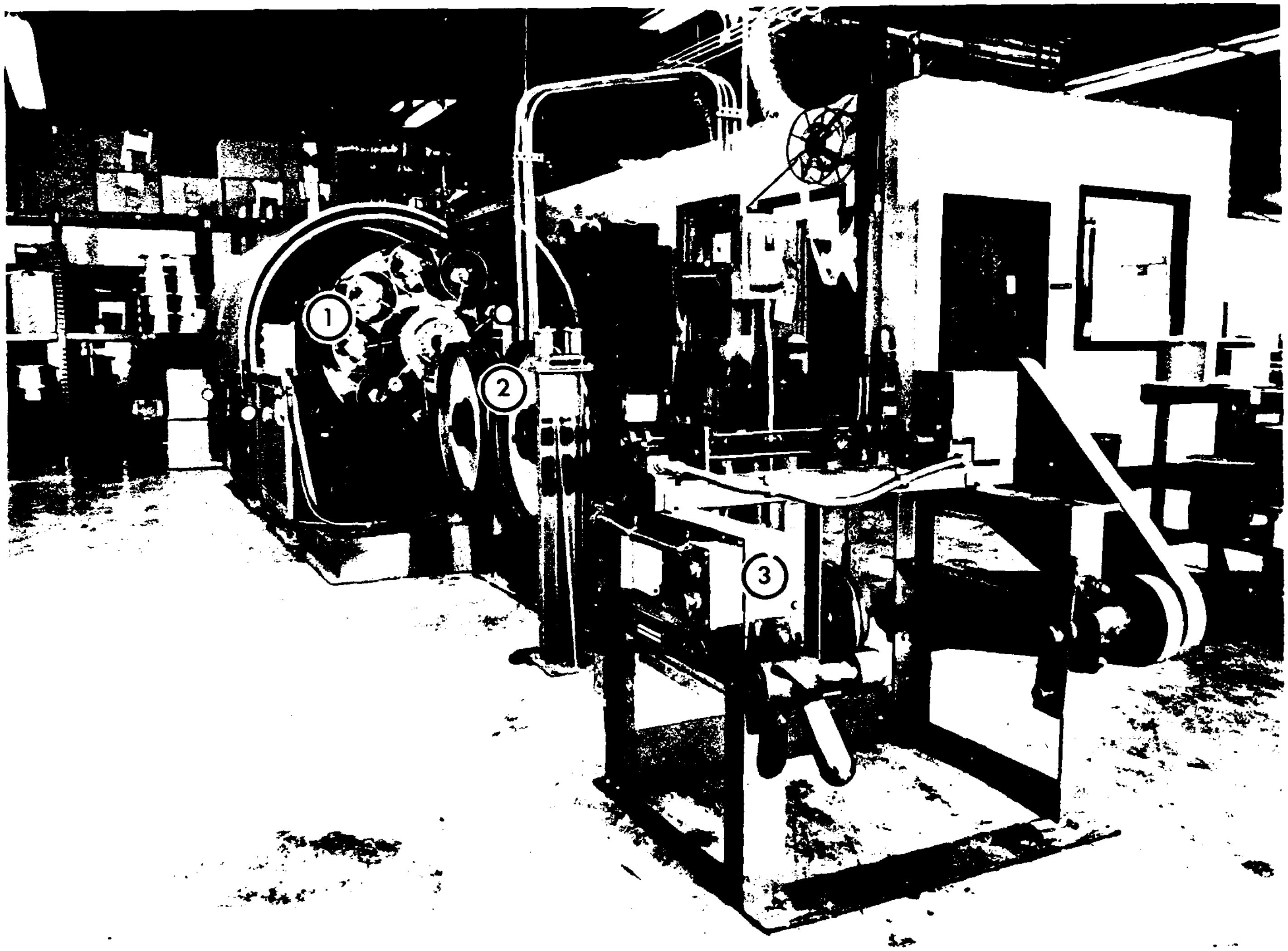


Figure 6. Kevlar Stranding Station

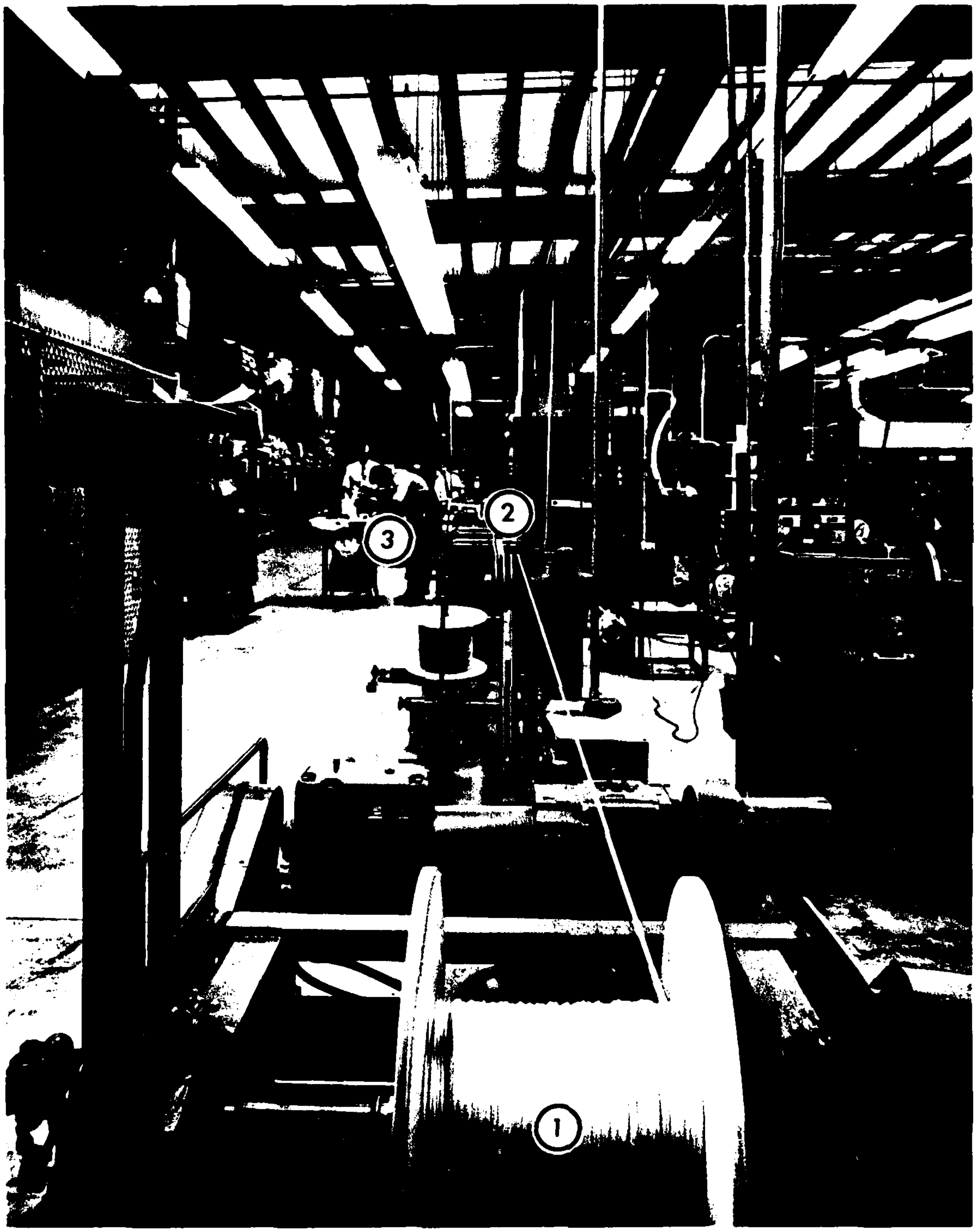


Figure 7. Final Jacketing Station 2" Extruder Line

required to drive a speed indicating meter. The tech-generator is on order. No other problems are evident at this time which may result in a delay of the operation of this station. This unit will have a laser micrometer system for diameter control as outlined in Section 1.2.1.3. This system is being upgraded to handle 4 km continuous lengths on the payoff and take-up units (Figure 7, items 1,3).

1.2.1.9 Final Cable Respooling Station

At this station (Figure 8, E9) the cable will be spooled onto the shipping reel, inspected for visual defects, and cut into 1 km ±5 meter lengths.

The production speed of this equipment is in excess of 40 km/40 hour week. It can operate at rates in exess of 34 meters/minute.

The equipment has a preset counter that will stop it automatically when the desired length (1 km) has been spooled onto the shipping reel.

Steps are to be taken to improve the payoff tension control of the unit. At this time it appears that the installation

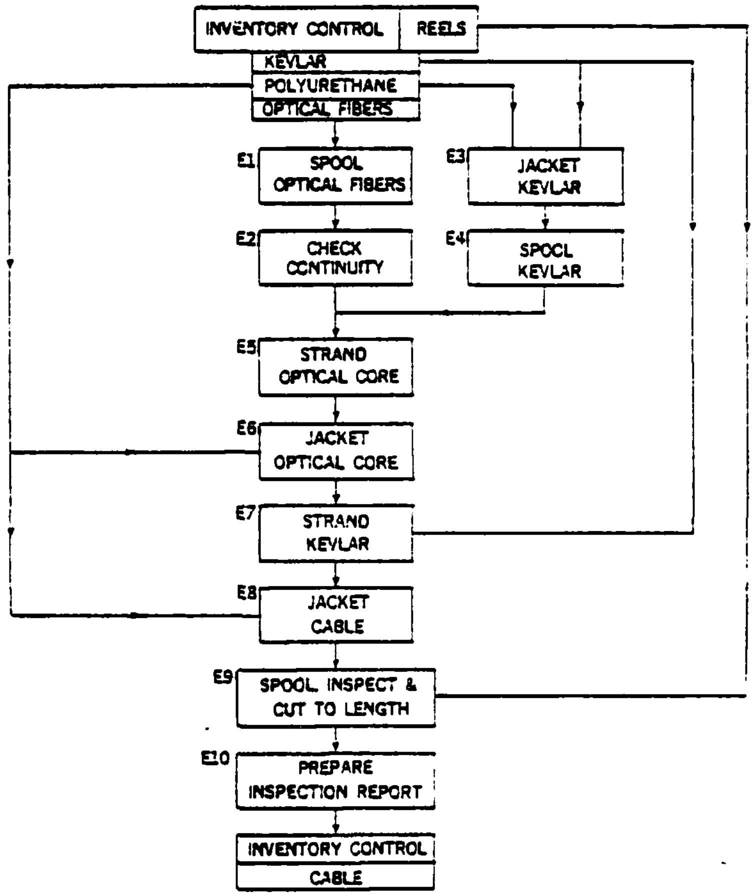


Figure 8. Cable Fabrication Flow Chart.

of a Eaton-Dynamatic multi-trol system will provide the uniform tension required to prevent cable damage. More discussion with the bendor is required before components are placed on order. Payoff controls are standard in the cable industry; therefore, no slip in the program is anticipated.

1.2.2 Cable Measurements

The modifications that were proposed for each of the measurement stations were intended to: (1) expedite the measurements procedure by increasing overall efficiency (2) facilitate configuration changes in existing equipment and fixturing thereby reducing design time, (3) eliminate equipment redundancy by utilizing the same stations for different phases of the program.

In order to meet those objectives certain information was required: (1) the amount of time presently being consumed for measurements and (2) the existing devices, material or personnel that could be employed to support the effort. The first requirement was satisfied by requesting a time study which revealed that some testing exceeded the maximum allowable time for completion; this is most evident for the numerical aperature test. Other results indicate that improvement is necessary on fiber handling time (see Tables 1, 2, 3 and 4) and optical detection peaking.

The second requirement was satisfied by utilizing existing EOPD fiber couplers and implementing the design of a special fixture which could support a fiber or cable and perform a prealignment function for optical injection or detection purposes. This design was completed by EOPD personnel and is expected to eliminate approximately 75% of the time utilized in fiber/cable handling and optical peaking.

With reference to the proposed approach and the final evaluation plan, it became obvious that the same measurement equipment could be used for the incoming fiber evaluation and final cable measurements eliminating the need for redundant equipment and stations with the exception of the dimensional measurements which will utilize a new technique for incoming fiber evaluation and the proposed technique for the final cable inspection.

With reference to Figure 9, the previously mentioned fixture design is shown. This device will support all six fibers in the test cable while supporting the cable itself. By mounting this fixture on both ends of a cable, a cable can be changed to other measurement stations without consuming excessive time as previously mentioned. The "L" bracket shown in Figure 9 will be installed at each station facilitating quick connect/disconnect for any test.

TEST	TEST TIME	ALLOWANCES	TOTAL TIME
1) Dispersion	12.65 min.	1[illegible]	14.55 min.
2) Attenuation	10.49 min.	15%	12.06 min.
3) Numerical Aperture	18.91 min.	15%	21.75 min.

TABLE 1

TIME STUDY RESULTS

STEP	DESCRIPTION	TIME
1.	Get spool for measurement	.77
2.	Prepare fiber output end	1.49
3.	Prepare fiber input end	1.32
4.	Inject light & peak	1.13
5.	Mount output end to fixture	.44
6.	Zero input pulse with scope & record delay	1.59
7.	Adjsut for maximum area under curve	2.23
8.	Check graph recorder range	1.0
9.	Record data	1.4
10.	Dismount and forward	1.23
	TOTAL TIME	12.65 MIN.

TABLE 2

DISPERSION TEST BREAKDOWN

STEP	DESCRIPTION	TIME
1.	Prepare fiber ends	6.15
2.	Adjust light for higher throughput	2.20
3.	Adjust light for greater throughput	2.35
4.	Adjust light for max. throughput	1.90
5.	Calculate 10% power	1.63
6.	Back-off fiber to 90% reading	3.58
7.	Read distance from monitor & record	.30
8.	Disassemble	.75
	TOTAL TIME	18.91

TABLE 3

90% POWER N.A. TEST BREAKDOWN

STEP	DESCRIPTION	TIME
1.	Prepare fiber ends	3.79
2.	Inject light	1.99
3.	Take data for long length	2.40
4.	Prepare short length	1.41
5.	Take data for short length	.90
	TOTAL TIME	10.49

TABLE 4

ATTENUATION MEASUREMENT BREAKDOWN

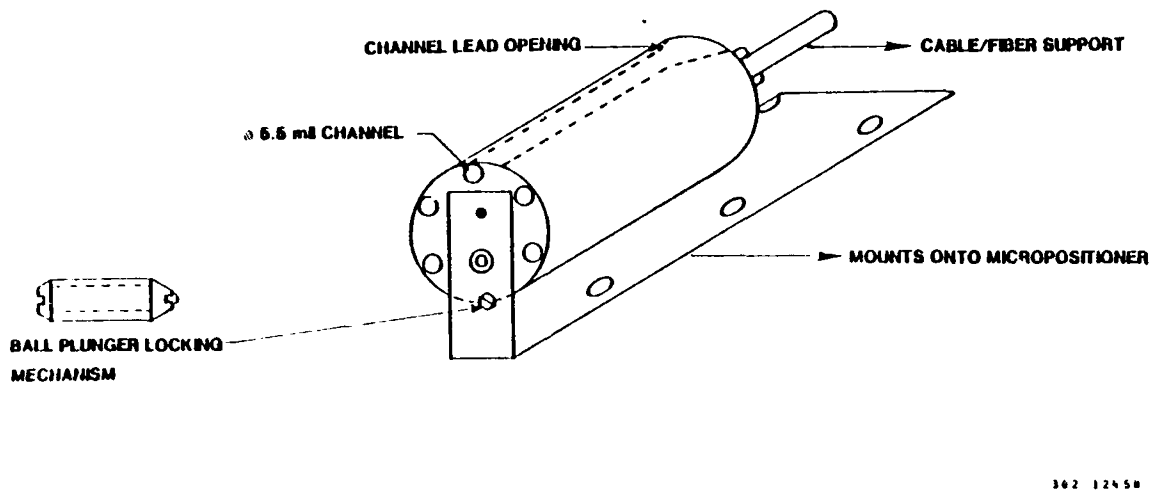
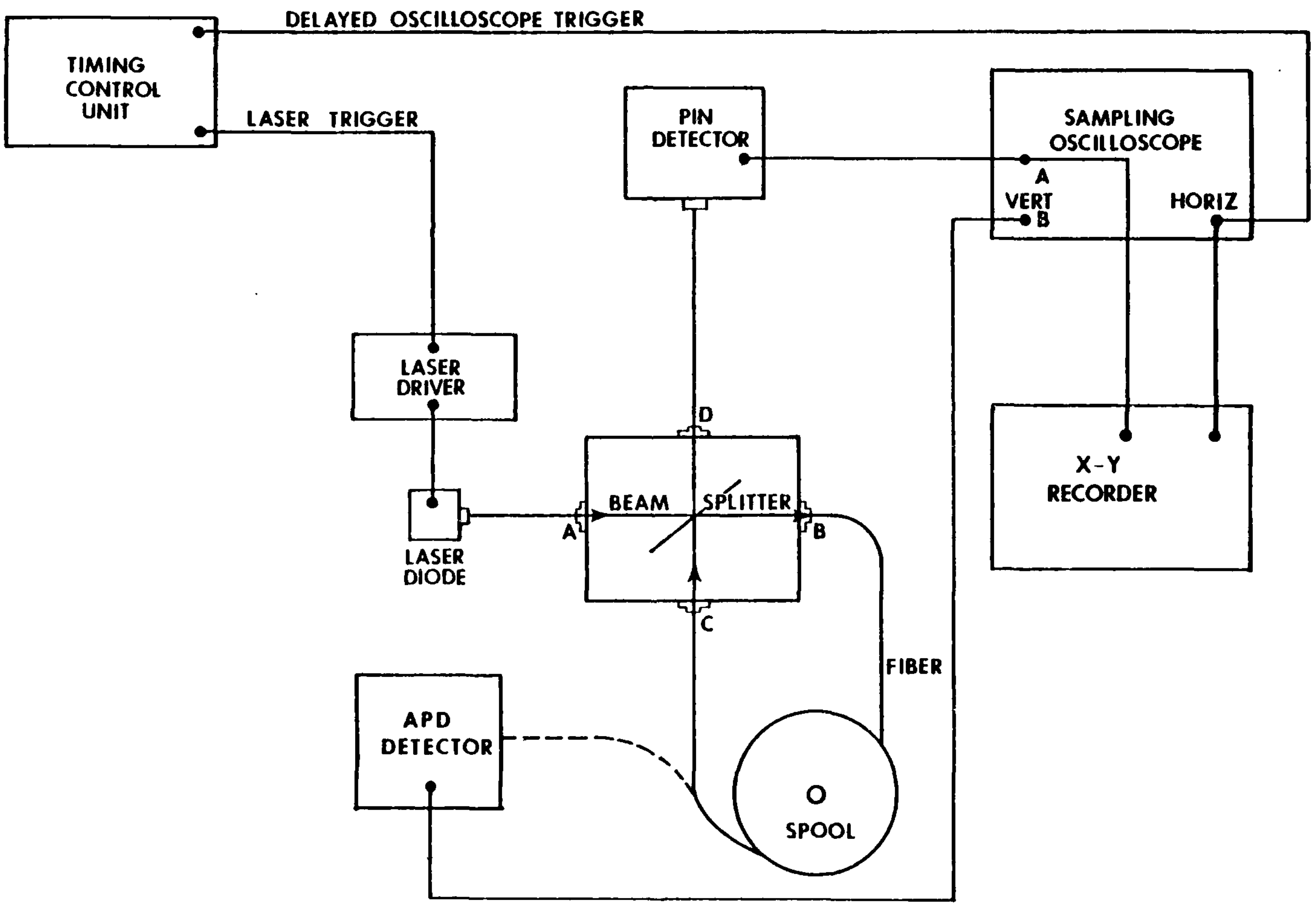


Figure 9. Disconnectable Barrel Type Fixture.

1.2.2.1 Dispersion Test Station

The present dispersion station, shown in Figure 10, required modification to improve input pulse monitoring capability. The present hardware uses a PIN diode to detect a portion of the laser diode output through a beamsplitter. While this is useful in determining the time reference for propogation delay measurements, it is not suitable for accurate input pulse monitoring for two reasons. First, the laser output may not be representative of the pulse injected into the fiber due to the fiber coupling properties. Secondly, the PIN diode has different time response characteristics than the APD.

While this method of imput monitoring has proved sufficient in the past, a modification was warranted on the basis of time requirements and troubleshooting capability. Even with the input pulse monitored on a periodic basis, perhaps once with each cable, the production rate would be reduced using the present technique. Further, in the event of problems during evaluation, the ability to quickly and accurately monitor the input pulse independent of the test fiber would save time in fiber and equipment troubleshooting.



DISPERSION MEASUREMENT STATION

Figure 10

302 12503

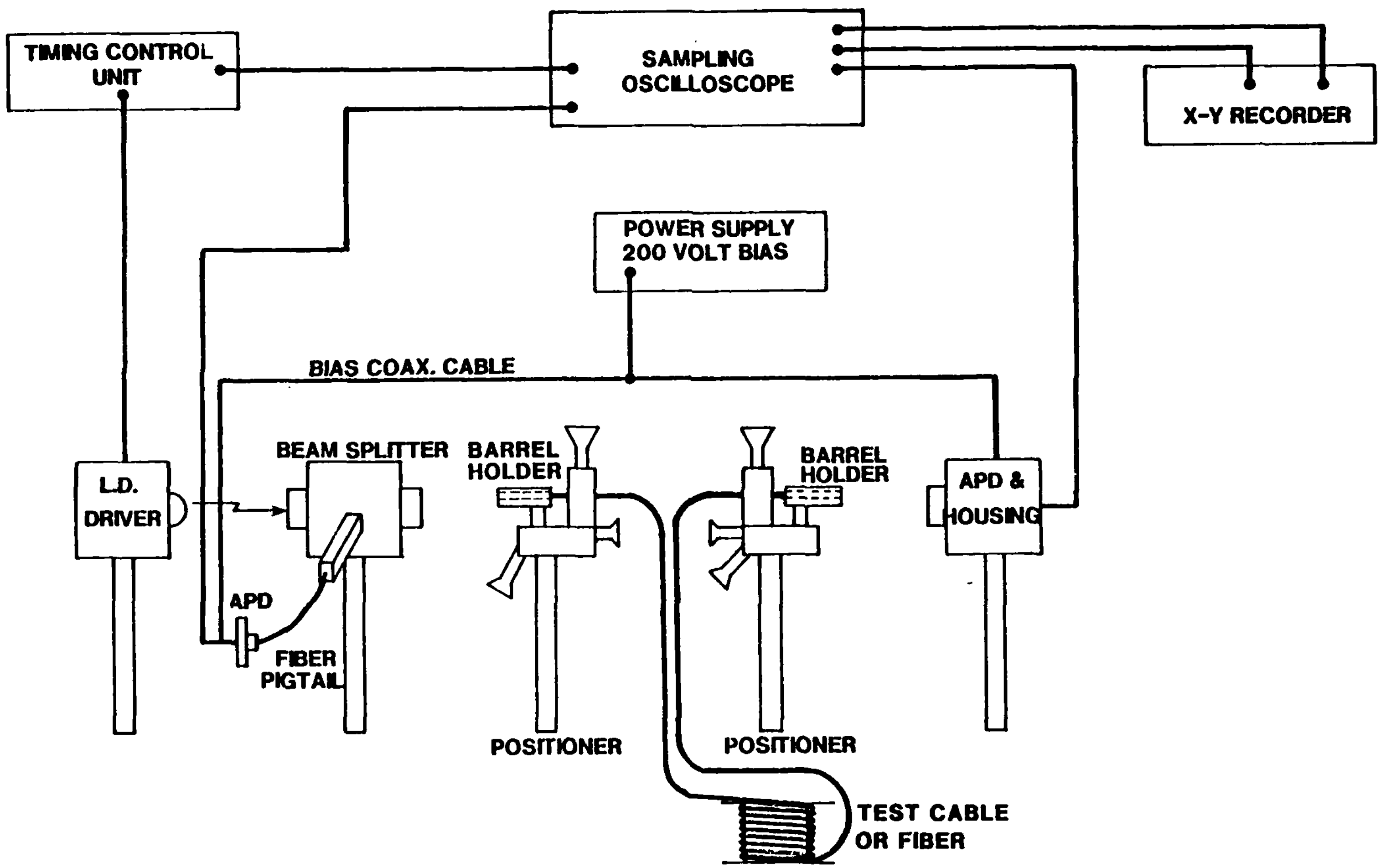
The dispersion station of Figure 11 was designed for the MM&T program. In addition to the fiber positioning fixture, which will increase the evaluation rate, a pig-tailed APD has been added as an input pulse monitor.

The APD will be selected for time response characteristics similar to the output index fiber typical of the fiber to be used in the MM&T program, will simulate the coupling conditions within the test fiber. A micropositioner will provide alignment of the fiber to the output of the beamsplitter.

1.2.2.2 N. A. Test Station

Presently, EOPD measures fiber numerical aperture with the apparatus of Figure 12. This equipment measures the material N. A. of a short fiber length. To measure the 90% power N.A. specified in the contract, new equipment was required.

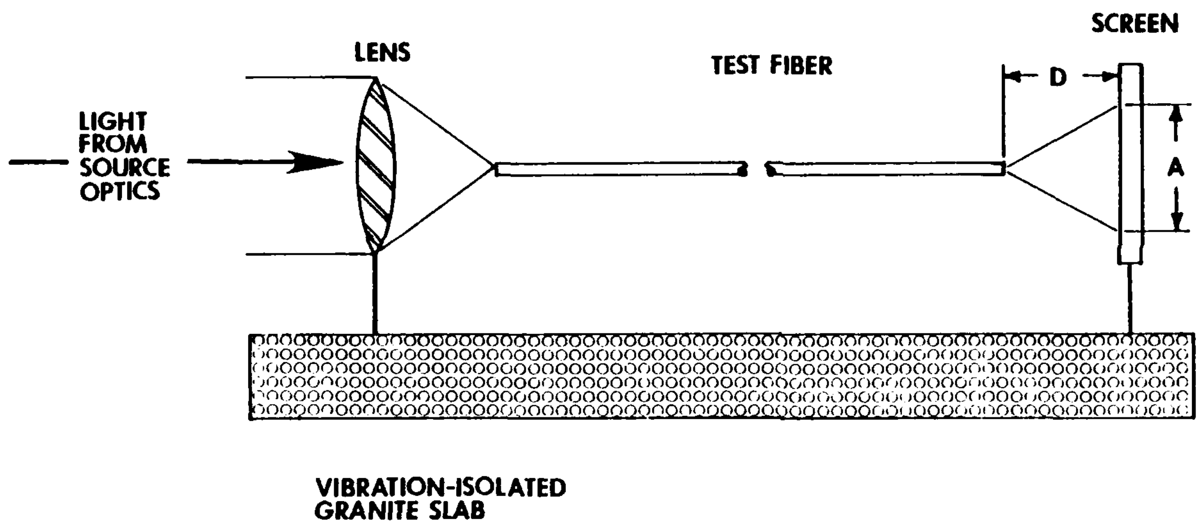
The station of Figure 13 was designed to measure the 90% power N.A. at the specified rate. With the fiber end very close to the large area detector, all the power output strikes the detector and is measured. A motorized positioner moves the fiber away from the detector, reducing



DISPERSION TEST MEASUREMENT STATION

Figure 11

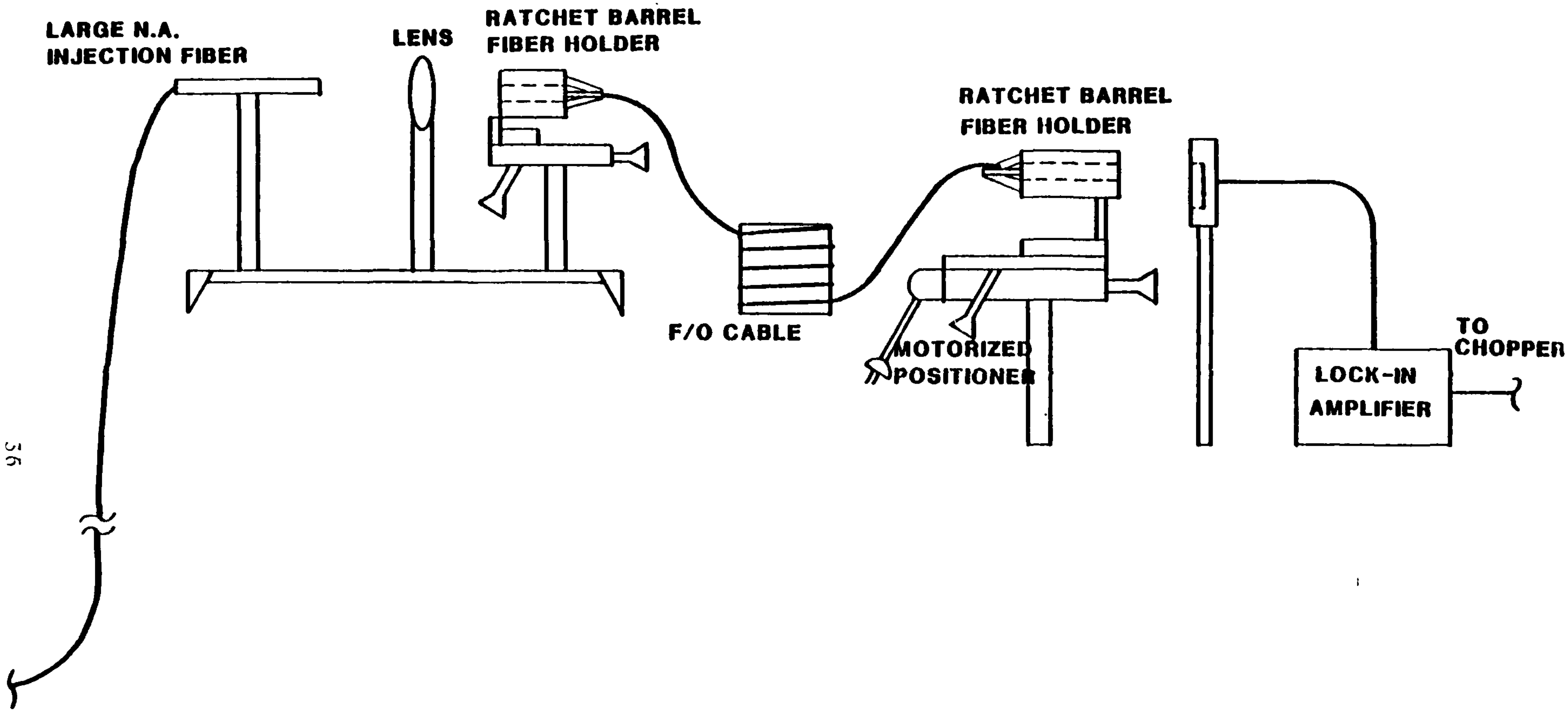
302 12454



MATERIAL NUMERICAL APERTURE MEASUREMENT

Figure 12

302 10027



90% POWER N.A. MEASUREMENT STATION

102 12460

Figure 13

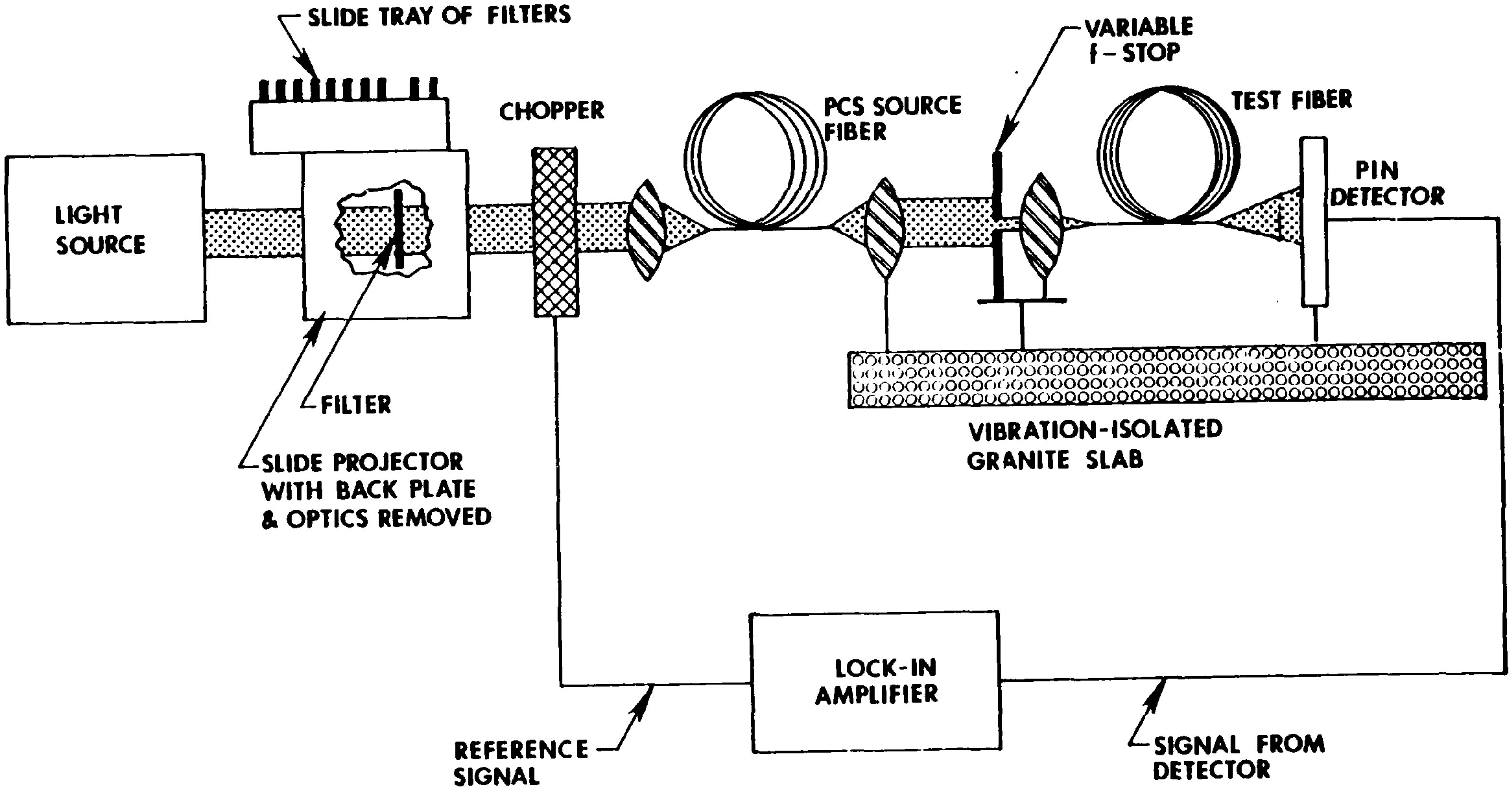
the detector field of view. At the point where the output drops 10%, the detector-fiber separation is recorded and the cone angle containing 90% of the power calculated.

A synchronous detection scheme is used to reduce the impact of stray light, enhance dynamic range, and implement available equipment.

The fiber positioning fixture of Figure 9 will again be used to improve speed in fiber handling.

1.2.2.3 Attenuation Measurement Station

The present attenuation station, diagrammed in Figure 14 is used to measure fiber attenuation at 37 wavelengths from 0.6 to 1.09 μm by the injection loss method. To meet the measurement requirements of the MM&T, additional filters are needed at 1.06, 1.10 and 1.20 μm as well as a long wavelength detector. In addition, a means of monitoring the input power at appropriate points during the test would be useful. With this capability, any changes in the input power resulting from bulb aging or source train misalignment, among others, during the test would be detected and included in the attentuation calculation.



ATTENUATION MEASUREMENT STATION

302 10030

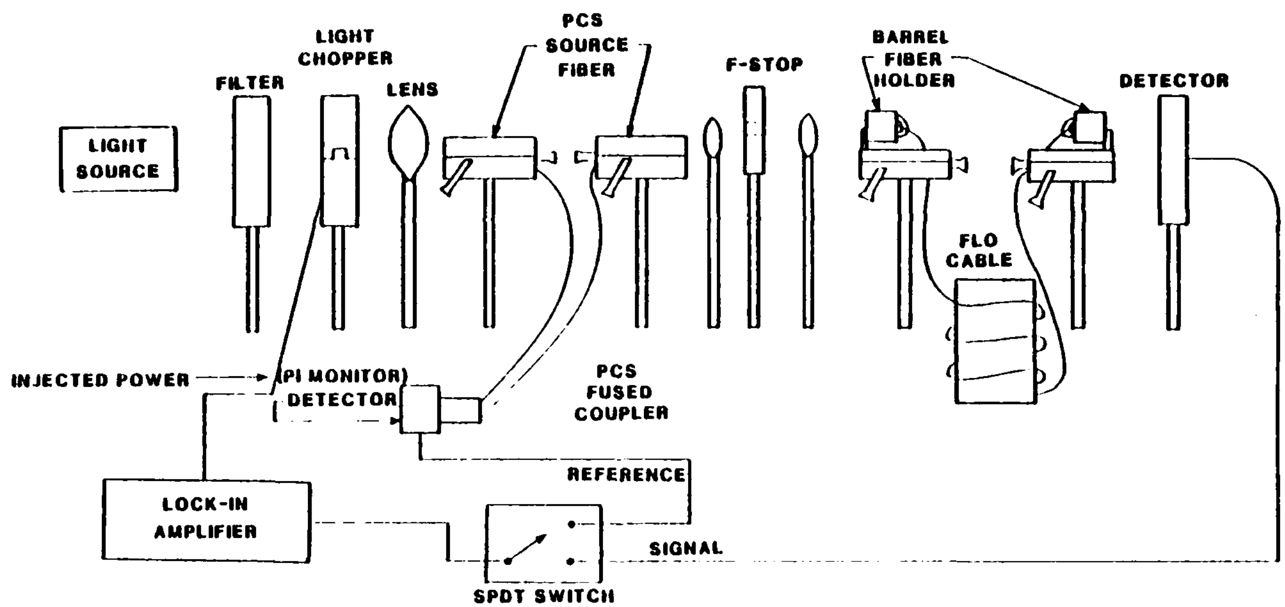
Figure 14

The station design of Figure 15 shows the addition of a monitoring coupler in the optical source train. This device, fabricated by EOPD, will tap off a fraction of the power in the fiber and direct it to a monitoring detector. By monitoring the optical input power downstream from the filters the power input at each wavelength can be monitored, rather than broadband measurements in front of the filters. Germanium detectors will be evaluated for use as long wavelength detectors.

The remainder of the station is the same as that presently used, with the exception of the fiber positioning fixture previously described.

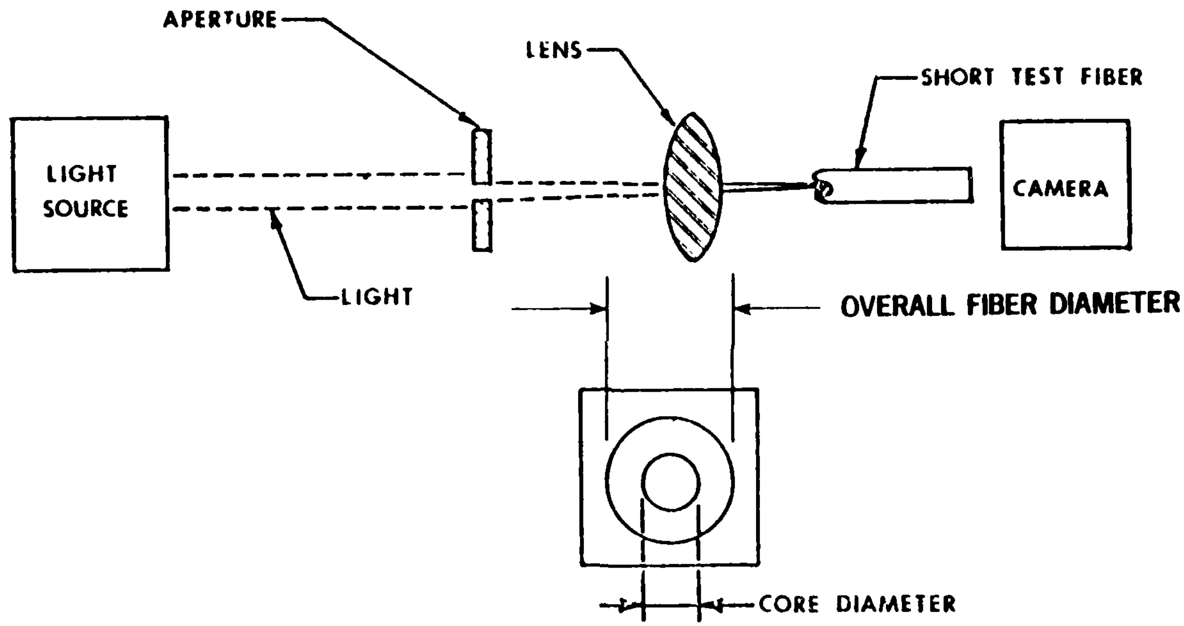
1.2.2.4 Dimensional Measurements Station

Fiber dimensional measurements are currently performed using the microphotographic equipment of Figure 16. However, in order to provide more reliable, less operator dependent dimensional measurements, the equipment outlined in Figure 17 was developed in a 1970 ITT R&D task. The equipment, based on a commercial video camera, provides an electronic means for measuring the fiber near-field output. The near-field image is projected onto the camera



Attenuation Measurement Station.

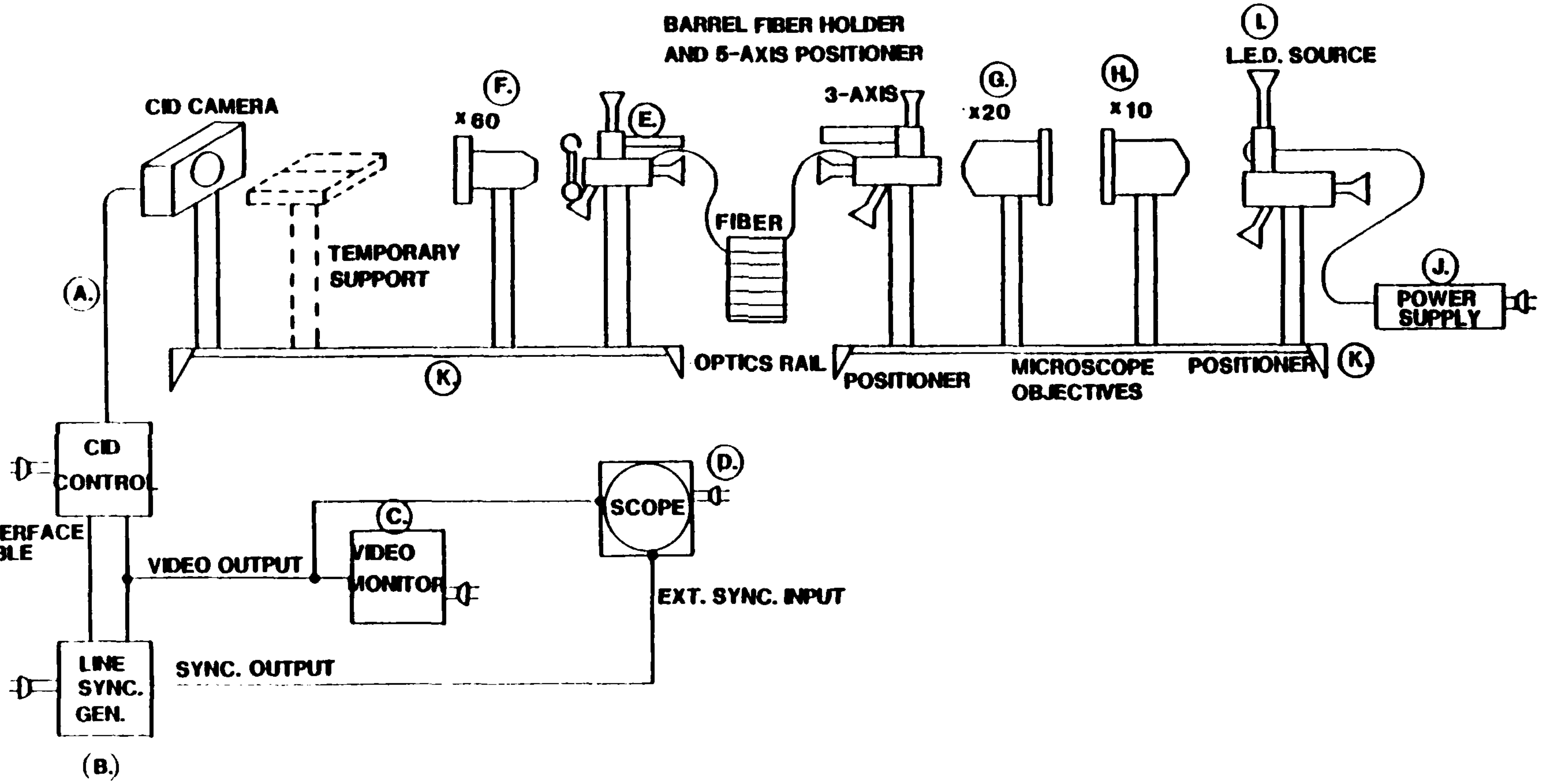
Figure 15



FIBER DIMENSIONAL MEASUREMENT STATION

Figure 16

302 10486



FIBER DIMENSIONAL MEASUREMENT STATION
(1979 CASE STUDY DEVELOPMENT)

302 17459

Figure 17

photosensitive region by the microscope objective. An electronic line selector permits the operator to choose any video line desired for intensity profile measurements on the oscilloscope. The oscilloscope time intervals are related to actual dimensions by calibrating the system with a back-illuminated stage microscope objective. This system is accurate to within ±0.5%.

The equipment of Figure 17 will be used for incoming fiber dimensional measurements. Cable dimensional measurements of the finished cable O.D. will be performed using calibrated micrometers.

The cable weight shall be measured in the Shipping Department using a Toledo balanced beam scale with a 1000 pound capacity and one pound increments. This station is calibrated twice a year. The cable weight shall be determined by weighing the finished cable on the DR-5 reel and then subtracting the weight of the reel.

1.2.2.5 Summary

The measurement station design phase is nearing completing. No unanticipated difficulties have been encountered, and the desired function has been obtained with each station.

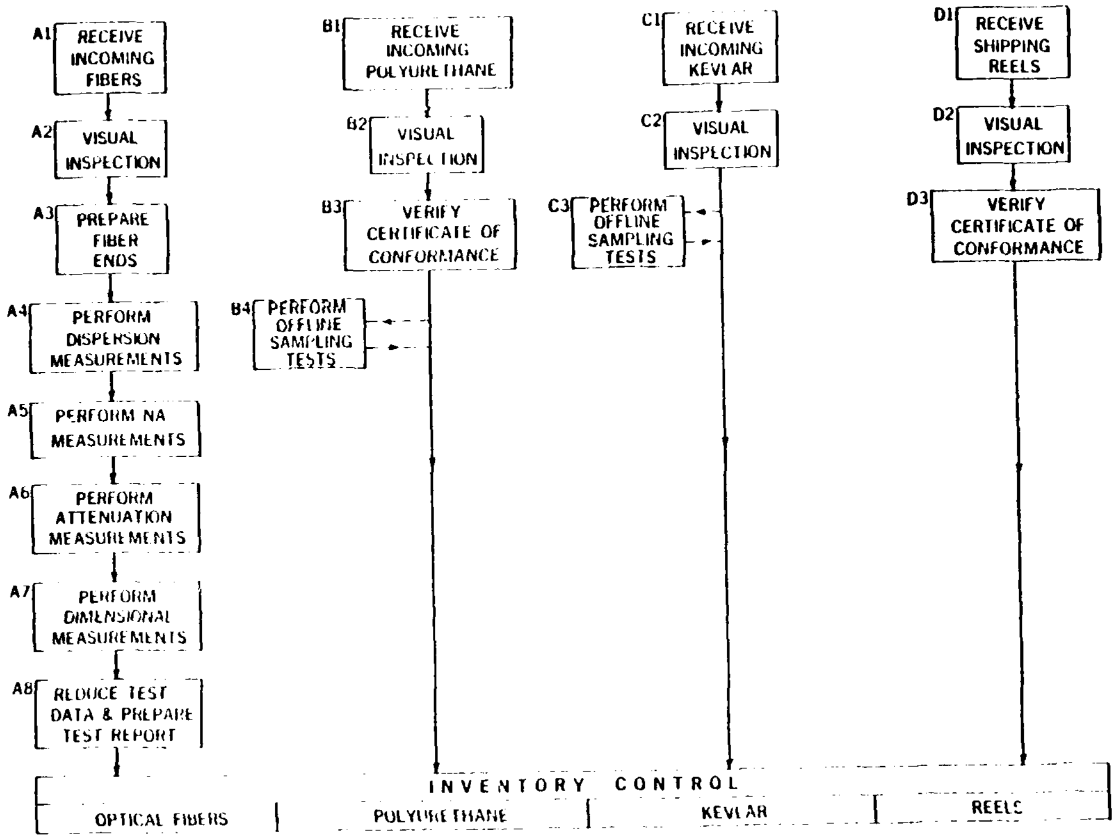
Future effort will include the assembly of the station designs described in the preceding sections. Following station assembly and checkout, an additional time study will be conducted to determine whether the new stations can perform the measurements required at the specified rate. Any problems encountered at that time will be corrected by design modifications, as required.

1.3 Flow Chart of Manufacturing Process

Figures 18a, 18b, and 18c show the flow of material and product through the proposed pilot line production facility. Each station is identified with a letter-number code.

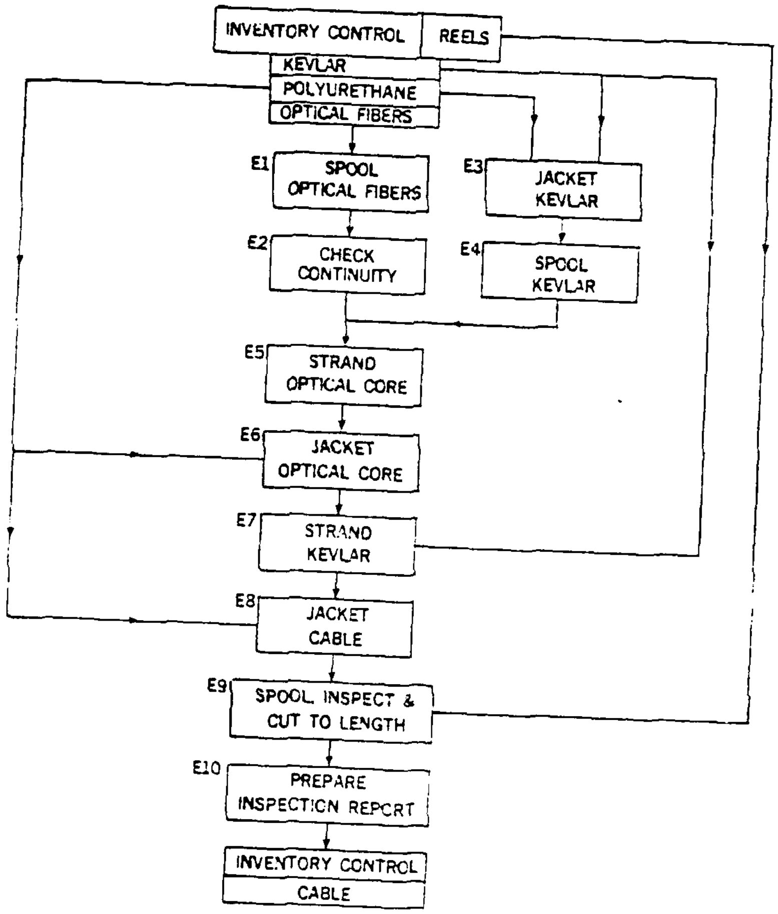
Plans are to produce cables in lengths of 4 kilometer, thus reducing setup time at each station considerable. The expected result of the above is to increase efficiency such that the overall production yield will be 86 percent.

Table 5 lists all operations with the expected production rate at each work station. (Major work stations have been discussed in Section 1.2). At this time in the program there is no obvious reason to believe that the proposed production rates cannot be met or exceeded. Only in the stranding of the optical fibers is it possible that the standard lay length of the cable may have to be increased from two inches to two and one half inches to meet the MM&T rate. In the next set of engineering cables to be produced samples of various lay lengths are to be produced and tested.



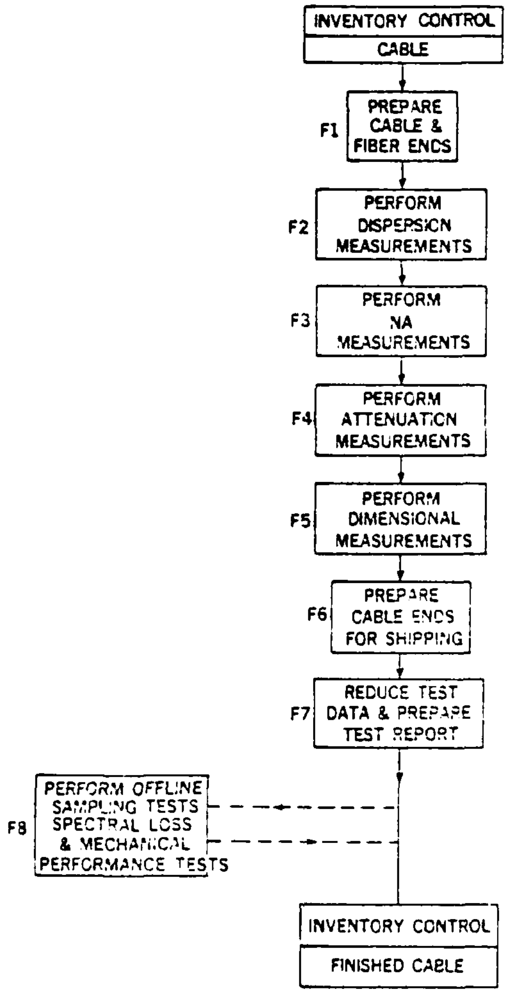
INCOMING INSPECTION & QUALITY CONTROL FLOW CHART

Figure 18a



CABLE FABRICATION FLOW CHART

Figure 18b



FINAL CABLE EVALUATION FLOW CHART

Figure 18c

TABLE 5a PRODUCTION RATE BY OPERATION

OPERATION #	OPERATION DESCRIPTION	SET-UP TIME hrs/km	RUN TIME hrs/km	TOTAL TIME hrs/km CABLE
A01	Receive Incoming Fibers	-	-	-
A02	Visual Inspection	0.020	-	0.184
A03	Prepare Fiber Ends	0.020	-	0.184
A04	Perform Dispersion Measurement	0.050	-	0.459
A05	Perform NA Measurement	0.050	-	0.459
A06	Perform Loss Measurement	0.050	-	0.459
A07	Perform Dimensional Measurement	0.050	-	0.459
A08	Reduce Test Data and Prepare Test Report	0.080	-	0.736
B01	Receive Incoming Polyurethane	-	-	-
B02	Visual Inspection	0.020	-	0.026
B03	Verify Certificate of Conformance	0.010	-	0.013
B04	Offline Sampling Tests	-	-	-
C01	Receive Incoming KEVLAR	-	-	-
C02	Visual Inspection	0.020	-	0.026
C03	Offline Sampling Tests	-	-	-
D01	Receive Shipping Reels	-	-	-
D02	Visual Inspection	0.050	-	0.056
D03	Verify Certificate of Conformance	0.050	-	0.056

TABLE 5b PRODUCTION RATE BY OPERATION

OPERATION #	OPERATION DESCRIPTION	SET-UP TIME hrs/km	RUN TIME hrs/km	TOTAL TIME hrs/km CABLE
E01	Spool Optical Fibers	0.030	0.090	0.827
E02	Check Continuity	0.050	-	0.344
E03	Jacket KEVLAR	0.130	0.370	0.574
E04	Spool KEVLAR	0.030	0.090	0.138
E05	Strand Optical Core	0.060	0.810	1.000
E06	Jacket Optical Core	0.260	0.540	0.918
E07	Strand KEVLAR	0.200	0.410	0.700
E08	Jacket Cable	0.230	0.157	0.918
E09	Spool, Inspect & Cut to Length	0.170	0.630	0.918
E10	Prepare Inspection Report	0.500	-	0.556

TABLE 5c PRODUCTION RATE BY OPERATION

OPERATION #	OPERATION DESCRIPTION	SET-UP TIME hrs/km	RUN TIME hrs/km	TOTAL TIME hrs/km CABLE
F01	Prepare Fiber & Cable Ends	0.750	-	0.833
F02	Perform Dispersion Measurement	0.800	-	0.918
F03	Perform NA Measurement	0.670	-	0.744
F04	Perform Loss Measurement	0.800	-	0.918
F05	Perform Dimensional Measurement	0.800	-	0.918
F06	Prepare Cable Ends for Shipping	0.180	-	0.202
F07	Reduce Test Data and Prepare Test Report	0.660	-	0.734
F08	Offline Sampling Tests	-	-	-
	Total Production Time			15.277

1.4 Data and Analysis

Table 6 details the results of the fiber attenuation before cabling, after cabling, and change due to cabling. The attenuation of the fibers before cabling was measured with the fibers on plastic spools with a 4 1/2 inch drum. Variations in attenuation after cabling can be attributed to spooling conditions (high/low tension) prior to cabling or nonuniform winding of fibers onto the spools. Wide variation is determined to be fiber, not cable, related. This is under investigation and will be reported at a later date.

1.4.1 Results

The data in Table 6 indicates that by using Hytrel 7246 as a buffer to 1.0 mm, cabling losses increase directly with the amount of buffer applied. Also, the data indicates that the cabling losses decrease with the softer grades of Hytrel® (4056 and 5556) and with polyurethane Roylar E-80. Additional test data and a more complete analysis will be included with the first sample test report.

Table 6. Attenuation Data.

	Design No 1 1009 m .94mm Hytrel 7246 Attenuation (dB/km)*			Design No 2 1004 m 1.02mm Hytrel 7246 Attenuation (dB/km)*			Design No 3 935 m 1.14mm Hytrel 7246 Attenuation (dB/km)*		
	Before	After	Δ	Before	After	Δ	Before	After	Δ
Red	3.56	4.01	+0.45	4.14	4.74	+0.60	3.83	3.85	+0.02
White	3.63	3.71	+0.08	3.50	4.22	+0.72	3.34	4.19	+0.85
Blue	4.75	5.17	+0.42	3.49	3.89	+0.40	3.50	3.77	+0.27
White	3.45	3.34	-0.11	3.50	3.66	+0.16	3.57	4.33	+0.76
White	3.67	4.05	+0.38	3.43	4.34	+0.91	3.74	5.52	+1.78
White	3.55	3.67	+0.12	3.41	4.30	+0.89	3.57	4.21	+0.64
Avg	3.77	3.99	+0.22	3.58	4.19	+0.61	3.59	4.31	+0.72

	Design No 4 424 m 1.02mm Hytrel 4056 Attenuation (dB/km)*			Design No 5 445 m 1.02mm Hytrel 5556 Attenuation (dB/km)*			Design No 6 516 m 1.02mm Polyurethane E-80 Attenuation (dB/km)*		
	Before	After	Δ	Before	After	Δ	Before	After	Δ
Red	4.15	4.81	+0.66	4.34	4.67	+0.33	5.33	4.65	-0.68
White	4.59	5.06	+0.47	4.20	4.57	+0.37	4.63	4.83	+0.20
Blue	5.29	4.96	-0.32	4.49	4.67	+0.18	4.63	4.75	+0.12
White	4.63	4.94	+0.31	4.18	4.91	+0.73	4.31	4.23	-0.08
White	4.69	5.01	+0.32	4.56	4.23	-0.33	4.34	4.22	-0.12
White	4.80	4.95	+0.15	5.02	4.80	-0.22	4.32	4.74	+0.42
Avg	4.69	4.96	+0.27	4.46	4.64	+0.16	4.59	4.57	-0.02

*Attenuation measured at 0.82 μm wavelength and 0.089 injection NA

2.0 CONCLUSIONS

It is at present too early in the program for any firm conclusions to be derived from the data presented. Some observations can be made regarding the efforts completed to date, which may serve as preliminary conclusions. With regards to the buffer diameter variations and buffer materials tried on the first sample, it appears that none of the materials evaluated have any adverse effect on the manufacturing operation, with the possible exception of the polyurethane. The polyurethane appeared hard to wind and may effect high speed stranding operations. Attenuation data (Table 6) indicates that for the harder buffer materials of designs 1, 2 and 3, cabling loss increases as diameter increases.

No problems have been identified in the equipment or measurement station designs which will adversely effect performance on this contract. All milestones have been achieved on schedule.

3.0 PROGRAM FOR NEXT INTERVAL

Misestone achievements for the next quarterly interval are listed below:

a. Receive all polyurethanes

b. Begin fungus testing

c. Completion of 1st engineering sample tests

d. Completion of 2nd engineering sample fabrication and testing

e. Delivery of 1st engineering sample and test report

f. Order DR-5 reels for 3rd engineering sample and confirmatory sample

g. Complete strander setup and begin runs to achieve 50% rate

h. Complete extruder setup and begin runs to achieve 0.918 hours/km rate

i. Receive, setup and make spooler operational

j. Order components and begin final assembly of test stations

4.0 PUBLICATION AND REPORTS

There have been no publications, conferences and/or talks made during the period on or associated with the research, study or development under contract.

5.0 IDENTIFICATION OF PERSONNEL

The following is a list of the names of personnel working on the program who are considered professional and skilled technical personnel. The task performed and the manhours of work performed by each during the interval of the report is given. A description of the background of each is included in this section.

NAME	TASK	MAN HOURS EXPENDED
R. Hoss	Program Management	34
L. Ptaschek	Project Engineering	46
R. Thompson	Technical and Administrative	13
G. Bishop	Cabling Equipment Engineering	103
J. Smith	Cable Process Engineering	22
R. Kopstein	Cable Process Engineering	141
S. Mahurin	Measurements Supervision and Project Engineering	35.5
J. Ravita	Measurements Engineering	181.5
T. Armstrong	Quality Control	4

NAME: Robert J. Hoss

POSITION: Program Manager

EDUCATION:

Mr. Hoss was awarded a BEE degree from the University of Dayton in 1965. In 1972 he was awarded an MSEE degree from Southern Methodist University.

EXPERIENCE:

Mr. Hoss joined ITT Electro-Optical Products Division in November, 1978. As Program Manager of Fiber Optics, his responsibilities include providing program direction, program coordination and the preparation of schedule and cost plans to meet the requirements of major fiber optic programs within EOPD.

Prior to joining ITT, Mr. Hoss was Manager of Optical Communications Devices at Rockwell International, Electronic Devices Division. He also served as Chairman of the Rockwell Technical Committee on Fiber Optics. As Manager of Optical Communications Devices, Mr. Hoss' responsibilities included development of the optical communication components and subsystems for airborne, shipboard and ground systems. His systems development experience includes: fiber optic sensor systems for the TACAMO aircraft and power encoding, an 18-port single fiber data bus for the Autonetics information transfer system, a fiber optic telemetry system for HEW and the U.S. Navy Medical Center, a ground test fiber link for the B-1 crash data recorder, a 1/2 km underground link for remote radio control, a field cable link for the HAWK air defense missile system, and the development of optical transmitters and receivers in the 250 kilobit to 100 megabit range.

ITT ELECTRO-OPTICAL PRODUCTS DIVISION REVISION DATE 1 / 17/80

BIOGRAPHICAL INFORMATION

NAME: Lawrence E. Ptaschek

POSITION: Manager - Cable Production

EDUCATION:

Mr. Ptaschek was awarded a BS degree in Mechanical-Industrial Engineering from Drexel Institute of Technology in 1972.

EXPERIENCE:

Mr. Ptaschek has been associated with ITT Electro-Optical Products Division for 1 year. As Manager - Cable Production in the Fiber Optics Cabling department, his primary responsibility is supervision of fiber optic cable production.

RESEARCH AND DEVELOPMENT

Prior to joining ITT, Mr. Ptaschek was associated with Philadelphia Insulated Wire Co. (PIW) for 9 years. As Senior Project Engineer from 1969 to 1972, Mr. Ptaschek's duties included development of extrusion techniques in the Teflon extrusion area for high temperature wires for aerospace and electronic industries. He also developed stranding techniques for silver plated and nickel plated close tolerance wire, and he installed the stranding department. As Manager of Manufacturing Engineering from 1974 to 1976, Mr. Ptaschek was responsible for all research and development and manufacturing processes. He designed and developed manufacturing techniques for a fire alarm cable (Class E) for New York City, developed extrusion techniques for PVC building wire products (including two PVC-nylon tandem lines), and developed extrusion and cabling techniques for Tefzel insulated nuclear power plant cables.

ADMINISTRATIVE

From 1972 to 1974 Mr. Ptaschek was Quality Assurance and Rewind Supervisor at PIW. In addition to the responsibility for establishing quality assurance procedures, he supervised five inspectors, one technician, one foreman and 14 rewinders. From 1976 to 1978 Mr. Ptaschek was Plant Manager at PIW. In this capacity he assumed complete overall responsibility for production, manufacturing engineering, plant maintenance, industrial engineering-cost estimating, and quality control. He supervised more than 100 persons in this position.

NAME: Robert E. Thompson

POSITION: Manager, Fiber/Cable/Measurements R&D

EDUCATION:

Mr. Thompson was awarded a BS degree in Electrical Engineering from Worcester Polytechnic Institute in 1974.

EXPERIENCE:

Mr. Thompson has been associated with ITT Electro-Optical Products Division for two years. As Manager of Fiber/Cable/Measurements R&D, his responsibilities include the development and fabrication of all optical fiber cables. As a Senior Project Manager, he has additional project management responsibility for several development contracts. Mr. Thompson has extensive experience in project engineering management.

RESEARCH AND DEVELOPMENT

During his association with the Electrical Cable Division of U.S. Steel Company, Mr. Thompson was heavily involved in the development of TOW cables for such programs as STASS, BQQ-5, ITASS, and MSS. As Cable Engineering Manager at the Cable Hydrospace Division of ITT, Mr. Thompson worked on the development of the RUWS Cable System, designed and developed the first successful TOW cable to include optical fibers, and designed and developed the umbilical cable for the SEA GUARD program. The RUWS and SEA GUARD cables are the first large diameter ocean cables to successfully utilize synthetic aramid fibers for strength.

In addition to his line manager responsibilities, Mr. Thompson is currently the Project Engineer for a major optical fiber systems development contract at EOPD.

TECHNICAL

Mr. Thompson has extensive experience in the areas of optical fiber system design, mechanical design, stress analysis, electro-magnetic propagation and computer simulation.

NAME: Gary H. Bishop

POSITION: Associate Manufacturing Engineer

EDUCATION:

Mr. Bishop was awarded a BS degree in Engineering Science and Mechanics from Virginia Polytechnic Institute and State University in 1979.

EXPERIENCE:

Mr. Bishop joined ITT Electro-Optical Products Division in July 1979. As Associate Manufacturing Engineer in the Cable Production Group, he is responsible for assuring that cable manufacturing operations are maximized and processing problems are solved as they occur. He also assists in the selection of manufacturing equipment, installation, and start-up.

ITT ELECTRO-OPTICAL PRODUCTS DIVISION REVISION DATE 3/22/79

BIOGRAPHICAL INFORMATION

NAME: John C. Smith

POSITION: Senior Project Engineer

EDUCATION:

Mr. Smith was awarded an Industrial Chemist degree from Universidea Technica del Estado, Santiago, Chile in 1958. He received a degree in Industrial Chemical Engineering from Escuela de Ingenieros Industriales, Santiago, Chile in 1959. The Industrial Chemical Engineering degree is equivalent to an MS degree in the United States.

EXPERIENCE:

Mr. Smith has been associated with ITT Electro-Optical Products Division for five years. He is presently responsible for the design and development of all fiber optic cables and, in particular, the materials involved in cable fabrication. In addition, Mr. Smith supervises both R&D and manufacturing activities in the Fiber Optic Cabling Laboratory.

RESEARCH AND DEVELOPMENT

Mr. Smith is responsible for the research and development of fiber optic cables at ITT EOPD. Besides numerous R&D projects, cables have been developed for the following contracts: (a) NELC (1974-1975), (b) ECOM (1975), (c) Torpedo guidance cable, (d) NELC-LINK (installed at Ft. Meade in 1977), (e) NOSC-Hawaii fiber optic link, and CORADCOM's Ultra Low Loss Fiber Optic Cable Assemblies.

During his association with General Cable Corp., Mr. Smith was Products Engineering Supervisor with responsibilities for the design and development of high temperature wire and cable serving Aerospace, Electronics and Specialty markets.

From 1960 to 1966, Mr. Smith was Manager of the Elastomers Laboratory at MADECO in Santiago, Chile, where he was responsible for compounds development of high voltage, power, control and communications wire and cable insulations.

TECHNICAL

Mr. Smith's area of expertise includes cable design, equipment and process development of polymers such as fluoropolymers, polyolefins, and elastomers. This experience includes compounding, processing and polymer selection to suit particular performance requirements.

MANUFACTURING

While at General Cable Corporation, Mr. Smith functioned as Manufacturing Engineer with responsibilities in product and process development, cost reduction and interplant operations.

ITT ELECTRO-OPTICAL PRODUCTS DIVISION REVISION DATE 1/17/80

BIOGRAPHICAL INFORMATION

NAME: Robert Kopstein

POSITION: Senior Cable Engineer

EDUCATION:

Mr. Kopstein was awarded a BSEE degree in Electronics from the University of Wisconsin in 1972.

EXPERIENCE:

Mr. Kopstein has been associated with ITT Electro-Optical Products Division for 1 year. As a Cable Engineer in the Fiber Optics Laboratory, his present responsibilities include cable design combined with research and development to improve cable performance characteristics.

Prior to joining ITT, Mr. Kopstein was associated with the Rochester Corporation where he participated in research and development of new materials and designs for better product performance. In 1977 he developed and designed the first diving umbilical cable manufactured at the Rochester Corporation. Some of his other accomplishments at the company included the development of: equations to predict all electrical characteristics of coaxial cables prior to manufacturing; computerized methods to design mechanical characteristics on armored cables and coaxial cables; and improved manufacturing techniques for fiber optics handling and cabling using the available equipment.

ADMINISTRATIVE

From 1972 to 1976, Mr. Kopstein was associated with Underwriters Laboratories, Inc., as Project Engineer. In this capacity he supervised one Engineering Assistant and two technicians. He managed from 30 to 40 projects in his position as Project Engineer.

MANUFACTURING

During his course of study at the University of Wisconsin, Mr. Kopstein developed a system for closed circuit video and TV transmission to all departments at the institution. He also fabricated integrated circuits with current manufacturing techniques.

TECHNICAL

Mr. Kopstein's technical expertise includes design and maintenance of a CCTV station at the University of Wisconsin, product safety evaluation at Underwriters Laboratories, and experience with armored cable at the Rochester Corporation.

ITT ELECTRO-OPTICAL PRODUCTS DIVISION REVISION DATE 4/5/79

BIOGRAPHICAL INFORMATION

NAME: Thomas G. Armstrong

POSITION: Senior Engineer, Quality Control

EDUCATION:

Mr. Armstrong was awarded a BS degree in Physics from Virginia Polytechnic Institute and State University in 1967.

EXPERIENCE:

Mr. Armstrong has been associated with ITT Electro-Optical Products Division for one year. As Senior Engineer in the Quality Control department, his primary task is to provide quality control engineering and management of the quality control function to the Fiber Optics Laboratory. His duties include writing inspection and test specifications, contract review, determining the quality assurance content of proposed projects, and providing a customer interface on quality related matters.

RESEARCH AND DEVELOPMENT

Prior to joining ITT, Mr. Armstrong was associated with Sprague Electric Company, Hillsville, Virginia. From 1968 to 1969, he performed research and development work on capacitor designs and processes in the Research and Engineering Department at Sprague.

GOVERNMENT

While with Sprague, Mr. Armstrong was responsible for Q.P.L. testing on several styles of military grade electrolytic capacitors. This experience included work with Government inspection and audit representatives. The quality program at Sprague was qualified to MIL-Q-9858.

ADMINISTRATIVE

Mr. Armstrong served three years as Quality Assurance Manager at Sprague. His responsibilities in this position included the management of the total quality program in the plant and the supervision of 13 employees to implement this program.

MANUFACTURING

As a Manufacturing Engineer at Sprague, Mr. Armstrong's duties included design, construction and maintenance of manufacturing equipment. This responsibility also included troubleshooting manufacturing problems when related to equipment and all phases of engineering support to manufacturing.

NAME: Stephen L. Mahurin

POSITION: Senior Engineer

EDUCATION:

Mr. Mahurin was awarded a BS degree and an MS degree in Electrical Engineering from Southern Methodist University in 1973 and 1975, respectively.

EXPERIENCE:

Mr. Mahurin has been associated with ITT Electro-Optical Products Division for one year. As Measurements Supervisor in the Fiber Optics Laboratory, his responsibilities include the development of new fiber and cable measurement techniques and equipment and daily measurement operations.

RESEARCH AND DEVELOPMENT

Prior to joining ITT Electro-Optical Products Division, Mr. Mahurin was associated with the Collins Radio Group of Rockwell International as Project and Design Engineer for four years. In that capacity his primary responsibility was the development of optical fiber communication systems and hardware. As Project Engineer he was responsible for electro-optical and circuit design of a high reliability, high performance, low cost optical sensor operating in moderately harsh environments. Mr. Mahurin also performed as Project Engineer responsible for the design, fabrication, and performance testing of a prototype baseband NTSC color video optical fiber transmission link. His duties included system design, transmitter and receiver circuit design, source coupling evaluation, and link analog and video testing.

In addition, Mr. Mahurin performed as Design Engineer responsible for the design, fabrication and testing of a three-channel optical fiber digital link between the command post and a field radar of a transportable anti-aircraft missile battery. Some of his other projects at Rockwell International included: (a) design and testing of an optical fiber bundle system for interrack distribution of six reference frequencies in the Collins MX-108 FDM hardware; (2) research of optical fiber communication links; (3) development of design guidelines and procedures for low-noise preamplifiers and general communication links, and (4) design and evaluation of digital and analog links and their hardware for both single fiber and bundle applications with bandwidths from 10 kHz to 25 MHz.

NAME: James I. Ravita

POSITION: Measurements Engineer

EDUCATION:

Mr. Ravita was awarded an Associate in Psychology degree from Armstrong State College in 1974. In 1977 he was awarded a BS degree in Electronics-Engineering Technology from Savannah State College.

EXPERIENCE:

Mr. Ravita joined ITT Electro-Optical Products Division in November, 1978. As a Measurements Engineer in the Fiber Optics Laboratory, his primary responsibility is to develop instrumentation for the Measurements Department as necessary for single-mode fiber.

RESEARCH AND DEVELOPMENT

Prior to joining ITT, Mr. Ravita was associated with Northrop/Page Communications Engineers from 1977 to 1978. Working in the research and digital systems directorate, he developed an in-house fiber optic system (dc to 25 MHz digital and analog). Mr. Ravita also performed digital logic designs for space diversity antenna switching and designed digital interfacing for F-8 microprocessor applications. In addition, he designed printed circuit board layouts as required.

APPENDIX A

MM&T - 789898
CORADCOM TECHNICAL REQUIREMENTS

RUGGEDIZED TACTICAL FIBER OPTIC CABLE

1. SCOPE

This specification covers the detail requirements for low loss fiber optic communication cables for operation at .6328 µm, .82 µm, .85 µm, 1.06 µm, 1.10 µm, and 1.20 µm. The cables are lightweight, flexible, and rugged to withstand tactical field army environments.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

Specifications:

Military:

MIL-R-3241	Reels, Cable (Reels DR-5, DR-7, DR-8, RC-453, RL-159)
MIL-I-3930	Insulating and Jacketing Compounds, Electrical (For Cable, Cords, and Wire)
MIL-C-13777	Cable, Special Purpose, Electrical
MIL-P-22241	Plastic Sheet (and Film) Polytetrafluoroethylene (TFE-Fluorocarbon Film)
MIL-Q-9858A	Quality Program Requirements

Federal:

L-P-390	Plastic, Molding Material, Polyethylene, Low and Medium Density

Standard:

Military:

MIL-STD-810	Environmental Test Methods
MIL-STD-1678	Fiber Optic Test Methods and Instrumentation

3. REQUIREMENTS

3.1 Visual and Dimensional

3.1.1 Cable - The cable design and construction shall be such as to enable it to meet the performance requirements specified herein. The length of the cable shall be 1 km ± 5m, the diameter of the cable shall not exceed 6.4 mm (.250"), and the weight shall not exceed 34 kg (75 lb.) per kilometer for a cable containing six optical fibers. No metallic parts are permitted. Substitution of materials may be made only with the approval of the government.

3.1.2 Optical fibers - The optical fibers which are used in the cables shall have a graded index profile and shall be of a high purity silica base construction to achieve the tensile strength and transmission properties herein specified. The core shall be a minimum of 50 um, and the overall diameter shall be 125 um ± 6 um. All fiber lengths used in the cables shall have been proof tested to a minimum tensile strength of 100,000 psi.

3.1.3 Jacketing: Jacketing shall be polyurethane in accordance with Type U of Specification MIL-I-3930

3.1.4 Interlayer Tapes: Interlayer tapes shall be in accordance with Specification MIL-P-22241.

3.2 Optical

3.2.1 Attenuation - The attenuation of each individual optical fiber in the cables shall not exceed 5 dB/km.

3.2.2 Numerical Aperture - The effective numerical aperture of each individual fiber in the cables shall be a minimum of 0.2.

3.2.3 Pulse Dispersion - The pulse dispersion of each individual fiber in the cables shall not exceed two nanoseconds per kilometer.

3.3 Mechanical and Environmental

3.3.1 Mechanical

3.3.1.1 Tensile Load - There shall be no breakage of individual fibers or other visible cable damage within the gage length after testing in accordance with 4.7.1.1 herein.

3.3.1.2 Finished Cable - There shall be no breakage of individual fibers or other visible cable damage and the cable shall meet the requirements of Paragraphs 3.7.1 and 3.7.2 of Specification MIL-C-13777 when tested in accordance with 4.7.1.2 herein.

3.3.2 Environmental - There shall be no breakage of individual fibers or other visible cable damage and the cable shall meet the requirements of paragraphs 3.2.1, 3.2.2 and 3.2.3 after completion of each of the tests specified in paragraphs 4.7.2, 4.7.2.1, 4.7.2.2, 4.7.2.3, 4.7.2.4, 4.7.2.5, and 4.7.2.6 herein.

3.3.2.1 Fungus: After test, there shall be no visible growth of fungus on any surface except sparse and tuberal development of the fungus spore, and no more than two unrelated minute colonies.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection - Unless otherwise stated in the contract, the contractor shall be responsible for the performance of all tests and inspection requirements as specified herein. Except as otherwise specified, the contractor may use his own or any other facilities suitable for the performance of required tests and inspections. The contractor shall maintain a quality assurance program in accordance with MIL-Q-9858A. Inspection records of the examinations and tests shall be kept complete and available to the government as specified in the contract. The contractor is responsible for ensuring that components and materials used are tested in accordance with the requirements of this specification and the referenced documents. The government reserves the right to perform any of the tests in this specification where such tests are deemed necessary to ensure that materials and services conform to requirements.

4.2 Classification of Inspection - Inspection shall be classified as follows:

a. First Article inspection (does not include preparation for delivery) (See 4.4.).

b. Quality conformance inspection (See 4.5).

4.3 Test plan - The contractor-prepared government-approved test plan, as cited in the contract, shall contain:

a. Time schedule and sequence of examinations and tests.

b. A description of the method of test and procedures.

c. Identification and brief description of each inspection instrument and date of most recent calibration.

4.4. First Article - Unless otherwise specified in the contract, the First Article inspection shall be performed by the contractor.

4.4.1 First Article units - The contractor shall furnish Ruggedized Tactical Fiber Optic Cables for First Article inspection.

4.4.2 First Article inspection - The First Article inspection shall consist of Table I and shall be performed in the order specified therein. No failures shall be permitted.

4.5 Quality conformance inspection - Quality conformance inspection shall consist of the examinations and tests specified in Tables II, III, and IV (Groups A, B, and C inspections, respectively). No failures shall be permitted.

4.5.1 Group A inspection - Each cable on contract or purchase order shall be inspected for conformance to the inspections specified in Table II.

4.5.2 Group B inspection - Group B inspection shall be inspected for conformance to the inspections specified in Table III.

4.5.3 Group C inspection - Group C inspection shall be inspected for conformance to the inspections specified in Table IV.

TABLE I - FIRST ARTICLE INSPECTION

Inspection	Requirement Paragraph	Test Paragraph	Test Quantity
Group A			
Visual & Dimensional	3.1	4.6.1	12 each, one-kilometer lengths wound on DR-5 Reels
Attenuation	3.2.1	4.6.2.1	
Numerical Aperture	3.2.2	4.6.2.2	
Pulse Dispersion	3.2.3	4.6.2.3	
Group B			
Tensile Load	3.3.1.1	4.7.1.1	3 each, 15-meter lengths
Finished Cable	3.3.1.2	4.7.1.2	3 each, length per MIL-C-13777
Group C			
High Temperature	3.3.2	4.7.2.1	6 each that passed Group A Inspection shall be subjected to all Group C tests.
Low Temperature	3.3.2	4.7.2.2	
Temperature Shock	3.3.2	4.7.2.3	
Humidity	3.3.2	4.7.2.4	
Fungus	3.3.2	4.7.2.5	
Vibration	3.3.2	4.7.2.6	The remaining 6 shall be allocated, one to each of the tests for Group C inspection.
Secure Cargo	3.3.2	4.7.2.6.1	
Loose Cargo	3.3.2	4.7.2.6.2	

TABLE II - GROUP A INSPECTION

Inspection	Requirement Paragraph	Test Paragraph
Visual and Dimensional	3.1	4.6.1
Optical:		
Attenuation	3.2.1	4.6.2.1
Numerical Aperture	3.2.2	4.6.2.2
Pulse Dispersion	3.2.3	4.6.2.3

TABLE III - GROUP B INSPECTION

Inspection	Requirement Paragraph	Test Paragraph
Mechanical:		
Tensile Load	3.3.1.1	4.7.1.1
Finished Cable	3.3.1.2	4.7.1.2

TABLE IV - GROUP C INSPECTION

Inspection	Requirement Paragraph	Test Paragraph
High Temperature	3.3.2	4.7.2.1
Low Temperature	3.3.2	4.7.2.2
Temperature Shock	3.3.2	4.7.2.3
Humidity	3.3.2	4.7.2.4
Fungus	3.3.2	4.7.2.5
Vibration	3.3.2	4.7.2.6

4.6 Test Procedures

4.6.1 Visual and dimensional - The finished cable shall be given a visual and dimensional inspection for conformance with the applicable requirements of Table I and II.

4.6.2 Optical - All measurements shall be made on 1 km lengths of cable wound on reels (See Section 6 NOTES).

4.6.2.1 Attenuation - The attenuation of each individual fiber in the cable shall be measured at .82 μm, .85 μm, 1.06 μm, 1.1 μm, and 1.2 μm. The attenuation is determined by first measuring the transmitted light intensity through the entire optical fiber waveguide length and the far field half-radiation angle, ϕ_L, at the end of the fiber. Then, without altering the launch end configuration, all but a one meter length is cut from the sample and the transmitted light intensity and far field half angle, ϕ_S, are measured through the one meter length. For true steady-state attenuation it is required that $\phi_S = \phi_L$. In both cases, the incident light-source output intensity is monitored to provide a base reference-intensity level. The attenuation is calculated from the relation

$$B = \frac{10 \log_{10} R_s / R_L}{L_L - L_S}$$

where B = attenuation in dB/km

R_S = ratio of the transmitted light intensity to the reference light intensity for the one meter waveguide length

R_L = ratio of the transmitted light intensity to the reference light intensity for the long waveguide length

L_L = initial waveguide length in km

L_S = 0.001 km

4.6.2.2 Numerical Aperture - The numerical aperture of each individual optical fiber in the cable shall be measured at .82 μm by first overfilling the launching end of the fiber with light. The output radiation pattern shall be measured and the 90% power numerical aperture shall be calculated. The 90% power numerical aperture is defined as sinϕ, where 90% of the output optical power is contained within an angle ϕ of the fiber axis.

4.6.2.3 Pulse Dispersion - The pulse dispersion of each individual fiber in the cable shall be measured by a method which is suitable to the government. One such method is Method No. 6050 of proposed MIL-STD-1678, "Fiber Optics Test Methods and Instrumentation".

4.7 Mechanical and Environmental - These tests are to be conducted after the Optical Tests of Paragraph 4.1 herein.

4.7.1 Mechanical - After each of these tests, the cable shall be examined for visible damage under 5X magnification.

4.7.1.1 Tensile load - The cable shall be subjected to a static tensile load of 181.44 kg (400 lb.) over a gage length of six meters for a period of one minute. The cable shall be clamped in such a manner that failure is not within 2.54 cm (1") of the point of clamping.

4.7.1.2 Finished cable - The cable shall be subjected to the finished cable tests of Paragraphs 4.5.4, 4.5.4.1, 4.5.4.1.1, and 4.5.4.1.2 of Specification MIL-C-13777 with the following exceptions:

a. A means shall be provided for monitoring the optical continuity of the fibers where electrical continuity of conductors is indicated in the test procedures.

b. All mandrel tests are to be conducted with a 5X cable OD mandrel.

c. Impact tests to be conducted with a loading of 0.415 kg-m (3 ft-lb).

d. Suitable alternatives to the test equipment shown in Figure 3, 4, and 5 of MIL-C-13777 will be considered.

4.7.2 Environmental - These tests shall be conducted with one kilometer long cables wound on DR-5 reels. After each of these tests, the cables shall be examined for visible damage under 5X magnification. In addition, the cables shall be tested for Attenuation in accordance with 4.6.2.1 herein.

4.7.2.1 High Temperature - Per MIL-STD-810, Method 501.1, Procedure II except that Steps 7 and 8 shall be omitted.

4.7.2.2 Low Temperature - per MIL-STD-810, Method 502.1, Procedure I except that Steps 4 and 5 shall be omitted.

4.7.2.3 Temperature Shock - Per MIL-STD-810, Method 503.1.

4.7.2.4 Humidity - Per MIL-STD-810, Method 507.1, Procedure II.

4.7.2.5 Fungus - Per Method 508.1 of MIL-STD-810. The test shall not be considered valid unless the controls per Paragraphs 3.1.3 and 3.1.4 of Method 508 show not less than profuse growth over 50% of the area after the 14th and 28th day of test.

4.7.2.6 Vibration - Per MIL-STD-810, Method 514.2. Provision shall be made for securing the ends of the cables to prevent damage to the cable during vibration.

4.7.2.6.1 Secured Cargo - Procedure X

4.7.2.6.2 Loose Cargo - Procedure XI

5. PREPARATION FOR DELIVERY

5.1 Preservation, packaging, and packing - Units shall be prepared for delivery as specified in the contract.

6. NOTES

6.1 MIL-STD-1678, "Fiber Optics Test Methods and Instrumentation", may be used as a guide for optical transmission test setups.

APPENDIX B

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